Operating and Service Manual

GOULD

GOULD BRUSH

MANUAL PART NO.
13-804715-4X

Please Don't use
for Calibration
See 3rd Edition*

THERMOCOUPLE AMPLIFIER

MODEL 13-4715-4X

Thermocouple type is indicated by the final digit (X) in the model number as follows:

Thermocouple Type	J	K	T	E	R	S
X	0	1	(2)	3	4	5

Ms or MRS DARA - Sales

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GOULD MODEL 13-4715-4X
THERMOCOUPLE AMPLIFIER
MANUAL REVISIONS
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MANUAL NUMBER 13-804715-4X

In keeping with the theme of constant improvement, the Gould Documentation Department maintains current manuals by periodically supplying the latest revisions. Please insert the following changes in ink, on the designated pages.

Schematic 288154, Sheet 1 (at back of manual) Drawing becomes revision level F.

Remove capacitor C202 .5ufd and replace it with two new capacitors C212 33ufd and C213 33ufd. Relocate new capacitor C202 1ufd between E2 and pin 10 of U223 as shown in schematic below.

REF: DCN 23765

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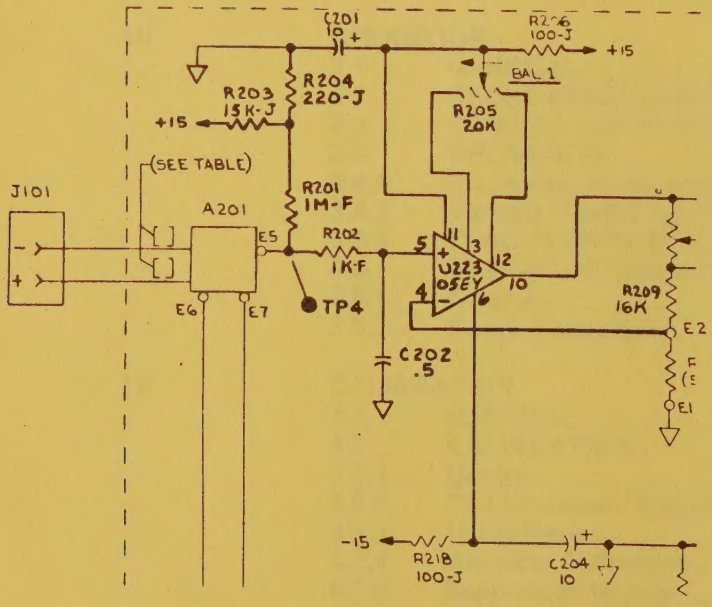
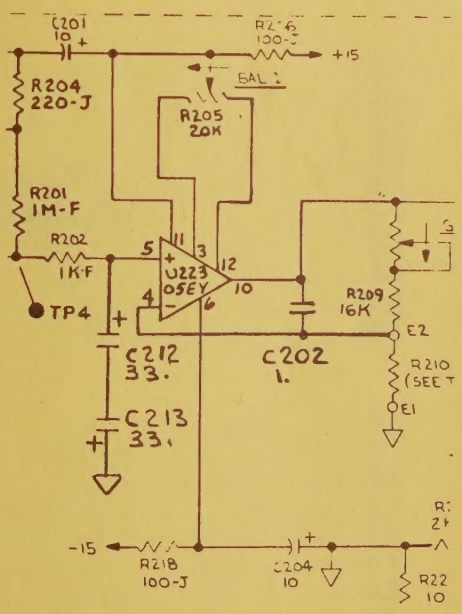


TO:



October 6, 1978

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SECTION I

GENERAL INFORMATION

1.1 SCOPE

This manual contains specifications, installation instructions and operating instructions for the Gould Thermocouple Amplifier, Model 13-4715-4X. In addition a theory of operation, calibration procedure and parts breakdown are included.

1.2 INTRODUCTION

1.2.1 Description

The Gould Thermocouple Amplifier (Figure 1-1) is a single channel, plug-in signal conditioner. It amplifies, linearizes and calibrates thermocouple signals, allowing for the accurate measuring and recording of temperature directly in degrees Farenheit or degrees Celsius. This amplifier also has calibrated zero suppression which further increases its effectiveness. It was designed for plug-in operation with Gould 110 Strip Chart recorders. When so used, it receives operating power directly from the pendrive amplifier of the recorder channel it serves. This reduces amplifier complexity, eliminates power supply noise pickup, and improves reliability.

This amplifier is not limited to operation with 110 Strip Chart recorders. When powered from a standard dc power supply that provides ±15 volts of suitable quality, it can be used with any Gould recorder or other readout device with similar input characteristics. Gould portable and rack mounted case assemblies are available.

Any amplifier will accommodate 6 common thermocouple types by means of interchangeable linearizers and input sections. Each amplifier is supplied complete with a standard, heavy duty, quick disconnect thermocouple input connector; mating connector, and a precise bridge type cold junction compensator for one type of thermocouple. These elements compensate for changes in ambient temperature at the amplifier input by maintaining the electrical equivalent of "Ice Point Temperature" (32 deg. F or 0 deg. C) at the internal reference junction.

A 15-point electronic thermocouple linearizer provides automatic correction for the non-linearity of each standard thermocouple type. Conformity to National Bureau of Standards thermocouple EMF output tables is maintained within ±1 deg. F (or ±0.55 deg. C) for standard thermocouple types "J", "K", "T", "E" and ±3° F (or ±1.5 deg. C) for thermocouple types "R" and "S" over the recommended tempreature range. Thus a low level, non-linear thermocouple signal is converted to a linear, high level output which can be displayed on any standard chart recorder or appropriate display device.

A fully floating input and common mode rejection greater than 120dB, permits operation with thermocouples which are grounded, floating or driven off-ground without experiencing "ground loops", damaged equipment or other problems associated with grounded input circuits.

FIGURE 1-1 GOULD MODEL 13-4715-4X THERMOCOUPLE AMPLIFIER

Table 1-1 gives the measurement ranges in degrees Celsius for the thermocouple types.

MODEL NO SUFFIX	THERMOCOUPLE TYPE	LINEARIZED RANGE
-40	J	-150 to + 1000° C
-41	K	-200 to + 1000° C
-42	T	-200 to + 400 °C
-43	E	0 to + 1000° C
-44	R	+ 500 to + 1760° C
-45	S	+ 500 to + 1760° C

TABLE 1-1 MEASUREMENT RANGES

Any 13-4715-4X amplifier for use with any thermocouple type in Table 1-1 may easily be converted to one of the other thermocouple types. The required conversion kit may be ordered separately. Ordering information is given in Section 1.4 SUPPLIES AND ACCESSORIES. Each conversion package contains the appropriate thermocouple input connector, mating connector, plug-in cold junction compensator and plug-in linearization networks. The conversion can be accomplished without tools in about 5 minutes.

The factory calibrated, dc output is ±1.0 volts full scale into 2 kilohms or greater, on all sensitivity ranges. This output is electrically compatible with the 110 Strip Chart recorder or other readout device with similar input characteristics.

Front panel controls include a seven position range switch plus a vernier to precisely adjust sensitivity. Celsius or Farenheit is selectable by a two position front panel switch.

Zero suppression controls are also on the front panel. These consist of a range switch with positions for -250, OFF, +250, +1000, and +2500 degrees, plus a precision-calibrated vernier. Zero suppression enables the user to cancel out a static, unwanted portion of the temperature span. Each range switch position has a resolution of one part per thousand. The maximum sensitivity of 50 degrees full scale may therefore be used on any temperature range from -250 degrees to +2500 degrees.

A POSITION control provides for zeroing the pen.

A red LED (light emitting diode) which indicates an open input circuit condition completes the front panel controls.

Low-pass output filtering is internally selectable to eliminate objectionable high frequency signal components. This filter is 3dB down at 5Hz with a roll-off of 20dB per decade and can be easily modified for operation at other cut-off frequencies.

1.2.2 Important Features of the Thermocouple Amplifier

1. Linearized Output
2. Cold Junction Compensation.
3. Direct readout in degrees F or C.
4. Fully adjustable, calibrated Zero Suppression.
5. Six calibrated measurement ranges plus a variable-sensitivity control allow setting any desired full scale degrees.
6. Available for use with all Thermocouple types in current use.
7. Open thermocouple indication.
8. Internally Selectable Frequency Response
   3 dB down at 5 Hz or
   3 dB down at 200Hz
9. Common mode rejection of 120 dB at DC and 80 dB at 60Hz permits operation in noisy industrial environments.
10. Accepts grounded, floating, or off-ground inputs.

1.3 SPECIFICATIONS

	Preamplifier Only
Measurement Range (Directly in degrees Fahrenheit or Celsius)	—250 to +2500 degrees*, dependent on thermocouple type
Attenuator Steps	50, 100, 250, 500, 1000 and 2500 degrees full scale, plus OFF
Attenuator Inaccuracy	±0.25% of calibrated step
Sensitivity Vernier	Multiplies calibrated setting up to 2.5 times
Input Circuit	Single-ended to floating common
Input Impedance	1.0 megohm
Maximum Source Resistance	100 ohms
Common Mode Rejection	
dc at 100 ohms unbalance	Greater than 120 dB
60 Hz at 100 ohms unbalance	Greater than 80 dB
Maximum Allowable Input Voltage	500 volts dc or peak ac from common to chassis
Zero Line Instability (After 15-minute warm-up)	
With Time	±0.1°C/24 hours
With Temperature	±0.05°C/°C ambient change
With Line	±0.05°C for 10% line change
Gain Instability (After 15-minute warm-up.)	
With Time	±0.03% of reading/24 hours
With Temperature	±0.03% of reading/°C ambient change
With Line	±0.01% of reading for 10% line change
Output Voltage	±1.0 volts into 2 kilohms or greater
Output Impedance	Less than 5 ohms
Non-Linearity (Over linearized range)	
Thermocouple types "J", "K", "T", and "E"	Within 0.55°C or 1.0°F
Thermocouple types "R" and "S"	Within 1.5°C or 3.0°F
Output Noise (on most sensitive range)	±0.5% of full scale
Frequency Response	
Internal Filter Off	3 dB down at 200 Hz
Internal Filter On	3 dB down at 5 Hz ±10%
Filter Rolloff	6 dB/octave or 20 dB/decade
Calibrated Zero Suppression	
Ranges	—250°, OFF, +250°, +1000° and +2500°
Resolution	±0.1% of suppression range
Non-Linearity	±0.25% of suppression range
Inaccuracy (at 25°C and Nom. line)	±0.5% of suppression range
Stability (After 15-minute warm-up.)	
With Time	±0.02% per week
With Temperature	±0.02% per °C ambient change
With Line	±0.02% per ±10% line change
Operating Temperature	0°C to +50°C (+32°F to +122°F)
Storage Temperature	—40°C to +75°C (—40°F to +167°F)
Humidity	95% at +35°C (+95°F) non-condensing
Vibration and Shock	Best commercial practice
Power Input	
Voltage, dc	±15V dc ±5% at 50 milliamperes
Line and Load Regulation	±0.5%
Ripple	5 millivolts rms maximum
Weight (preamplifier only)	3.6 lbs. (1.5 kilograms)
Dimensions (preamplifier only)	2.125" H x 5" W x 12.75" D (5.4 cm H x 12.7 cm W x 32.4 cm D). Depth dimension includes attenuator knob and chassis mounted connector.
Signal Input Connector	Standard, heavy duty, quick disconnect, thermocouple input mating connector supplied with each preamplifier.

*Limited by operating range of the thermocouple.

1.4 SUPPLIES AND ACCESSORIES

Extender Card and Cable Assembly 788956
(may be ordered separately)

Iron-Constantan (Type "J") Input Connector (Male) 288063-3

Chromel-Alumel (Type "K") Input Connector (Male) 288063-1

Copper-Constantan (Type "T") Input Connector (Male) 288063-2

Chromel-Constantan (Type "E") Input Connector (Male) 288063-4

Platinum-Platinum 10% Rhodium (Type "S") Input Connector (Male) 288063-5

Platinum-Platinum 13% Rhodium (Type "R") Input Connector (Male) 288063-5

Conversion Kit Assemblies
(may be ordered separately)

To convert any 13-4715-4X amplifier to the below thermocouple types	Order Number
Iron-Constantan (Type "J")	11-4308-40
Chromel-Alumel (Type "K")	11-4308-41
Copper-Constantan (Type "T")	11-4308-42
Chromel-Constantan (Type "E")	11-4308-43
Platinum-Platinum 13% Rhodium (Type "R")	11-4308-44
Platinum-Platinum 10% Rodium (Type "S")	11-4308-45

SECTION II

INSTALLATION

2.1 GENERAL

This section describes inspection checks to be made upon receipt of the Gould Thermocouple Amplifier, Model 13-4715-4X with a Gould 110 Recorder. It covers installation procedures, signal input connections, and outline dimensions.

2.2 INITIAL INSPECTION

Prior to attempting any electrical connections or operation, visually examine the unit for broken or loose knobs, dented or nicked panels and broken or chipped rear connectors.

2.3 INSTALLATION

2.3.1 Insertion

To install the amplifier into its appropriate slot:

a. Insert the amplifier into the recorder mainframe (component side up) being certain that the module is guided into the printed circuit card holder grooves.

b. Slide the amplifier into the enclosure until the rear output card edge connector is engaged.

c. Be certain that the front panel does not interfere with other panel surfaces, and that the holes in the amplifier securing brackets line up with the holes in the recorder mainframe.

d. Plug in the 2 pin thermocouple type input connector.

2.3.2 Removal

a. Unplug the input connector.

b. Carefully slide the entire amplifier out of the Gould 110 Strip Chart enclosure.

2.4 SIGNAL CONNECTIONS

2.4.1 Input Connection Hardware

NOTE: It is extremely important to use the proper 2 pin thermocouple type mating connector which correctly matches the thermocouple metals. A complete list of connectors can be found in Para. 1.4, Supplies and Accessories.

To connect thermocouple leads, proceed as follows:

a. Open male thermocouple connector by removing pan-head screws securing connector.

b. Identify thermocouple leads (Iron, Constantan, Chromel, etc.) and connect to proper lug. Lugs are stamped with abbreviated terms designating proper connections.

c. Assemble connector using screws removed in step 1.

2.4.2 Output and Power

The amplifier is designed to operate on + and -15 volt, 100ma regulated supplies. Output and power connections are provided through a 16 pin card edge on the rear of the amplifier (Figure 2-1). The mating connector is located in the recorder chassis.

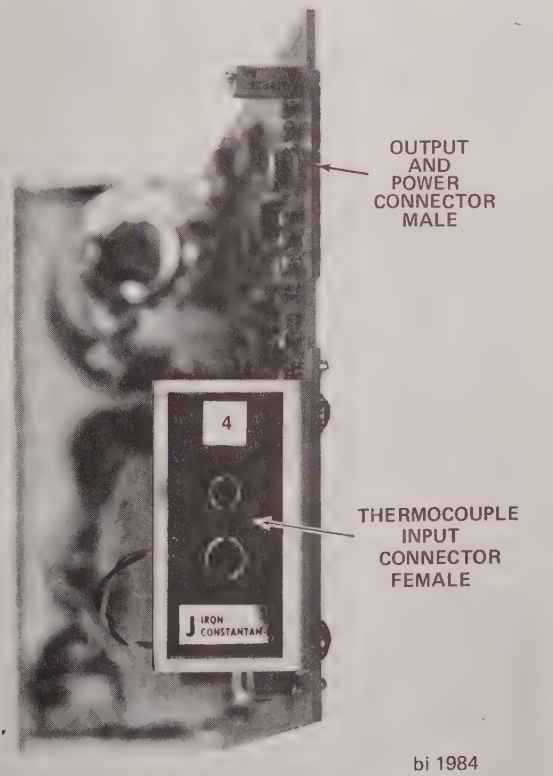


FIGURE 2-1 REAR VIEW

NOTE: If thermocouple is grounded or directly connected to any potential, the amplifier output or readout device (recorder) input must not be grounded as this will cause serious errors or possible damage to the instrument.

2.5 INSTALLATION OF THERMOCOUPLES AND EXTENSION WIRES

The following is a list of suggestions and recommendations which should be followed when installing thermocouples and extension wires.

Thermocouples

1. Avoid locating the thermocouple where it will be in a direct flame.
2. Locate it where the average temperature will be measured. It should be representative of the mass——if necessary use several thermocouples to obtain the average temperature.
3. Locate the thermocouple where the hot end can be seen if possible.
4. Immerse the thermocouple far enough so that the measuring junction is entirely in the temperature to be measured. Heat that is conducted away from the hot junction causes a lower reading.
5. Keep the connecting head and cold junction in a mild ambient temperature environment. This is extremely important in the Noble metal class.

Extension Wire

1. Use the correct extension wire for the thermocouple (see Table 2-1).
2. Observe the correct color coding (see Table 2-2).
3. If possible, install extension wires in a grounded conduit by themselves.
4. Do not run wires across or parallel to any AC lines. Induced emf's may effect the pyrometer.
5. Never run electrical wires in the same conduit with extension wires.
6. Thermocouple wires that must be spliced should never be soldered, but terminated in appropriate compression type connectors.

ISA CODE	CONDUCTOR & CHARACTERISTICS POSITIVE	NEGATIVE	TEMPERATURE RANGE (°F)	LIMITS OF ERROR STANDARD	SPECIAL	APPLICATION NOTES
J	Iron (Magnetic)	Constantan[2] (non-magnetic)	0 to 530 530 to 1400	± 4°F ± 3/4%	± 2°F ± 3/8%	Reducing atmosphere recommended. Iron oxides rapidly at elevated temperatures. NBS#561.
Jx	White	Red	0 to 400	± 4°F	± 2°F	Compensating extension wire for J curve.
T	Copper (Yellow metal)	Constantan (Silver metal)	-75 to 200 200 to 700	± 1½°F ± 3/4%	± 3/4°F ± 3/8%	Can be used in oxidizing or reducing atmospheres rust and corrosion resistant. Fine for low temperature.
Tx	Blue	Red	-75 to 200	± 1½°F	± 3/4°F	Compensating extension grade for T curve.
K	Chromel[1] (Non-Magnetic)	Alumel (Magnetic)	0-530 530 to 2300	± 4°F ± 3/4%	± 2°F ± 3/8%	Oxidizing atmosphere recommended. Vented protection tube suggested in reducing atmosphere.
Kx	Yellow	Red	0 - 400	± 4°F	± 2°F	Compensating extension grade for K curve.
Wx	Iron Green	Cupronel Red	75 to 400	± 6°F	—	Substitute for extension grade of type K leadwire.
E	Chromel	Constantan	0 - 600 600 to 1600	± 3°F ± 1/2%	± 3/8%	Oxidizing atmosphere recommended. Highest emf output of thermocouples commonly used.
Ex	Purple - Tan	Red	0 to 400	± 3°F	—	Compensating extension grade for E curve.
S	Platinum 10% Rhodium	Platinum	0 - 1000 1000 - 2700	± 5°F ± 1/2%	± 2½°F ± 1/4%	Oxidizing atmosphere recommended. Easily contaminated. The accepted laboratory standard in premium grade due to its reproductibility.
R	Platinum 13% Rhodium	Platinum	0 - 1200 1200 - 2700	± 5°F ± 1/2%	± 2½°F ± 1/4%	Same conditions as 10% above but has slightly higher emf. Mostly used in industrial applications.
Sx	Copper Black	11 Alloy Red	75 to 400	± 12°F		Compensating extension wire for S & R curves.

TABLE 2-1 THERMOCOUPLE APPLICATION DATA

ISA Alloy Code	Thermocouple Type	Body Color	Female Connector Number	Male Connector Number
J	Iron-Constantan	Black	288065-3	288063-3
K	Chromel-Alumel	Yellow	288065-1	288063-1
T	Copper-Constantan	Blue	288065-2	288063-2
E	Chromel-Constantan	Violet	288065-4	288063-4
S	Platinum-10% Rhodium	Green	288065-6	288063-6
R	Platinum-13% Rhodium	Green	288065-5	288063-5

TABLE 2-2 THERMOCOUPLE COLOR CODING

SECTION III

OPERATION

3.1 GENERAL

This section describes and illustrates the controls of the Gould Model 13-4715-4X Thermocouple Amplifier and provides instructions for proper operation. Before attempting to use the amplifier it is imperative that the operator completely understand the functioning of the controls and the required input/output specifications.

3.2 FRONT PANEL CONTROLS

Item numbers listed below correspond to circled numbers in Figure 3-1.

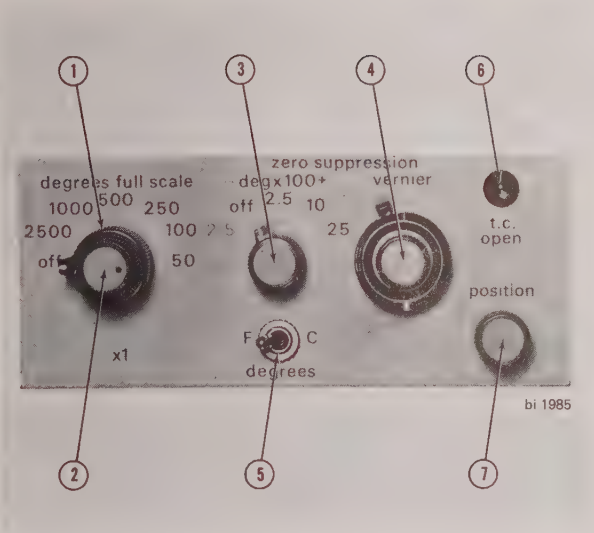


FIGURE 3-1 FRONT PANEL CONTROLS

ITEM NO	CONTROL	DESCRIPTION
1	DEGREES FULL SCALE (S201)	This is a 7 position rotary switch which allows selection of any of six sensitivity steps or OFF. In a clockwise direction, the positions are OFF, 2500, 1000, 500, 250, 100 and 50 degrees. **NOTE: In the OFF position, the amplifier power is not shut off, but the output circuit is disconnected from the amplifier circuitry and tied to common through 10K ohms.**
2	Sensitivity (R288) . . . . . (Coaxial with item 1, above)	This control is a variable resistor which may be used to set the full scale calibration to values other than the 6 distinct steps allowed by S201, above. In the X1 or full counterclockwise position (detented), the sensitivity is minimum and the DEGREES FULL SCALE is as set on switch S201. As the SENSITIVITY control is turned clockwise, the sensitivity is increased to a point such that, at full clockwise, the degrees full scale indicated by switch S201 is multiplied by 0.4 or less. This allows full scale to be continuously adjustable over the entire thermocouple range.
	ZERO SUPPRESSION (Items 3 & 4)	
3	DEG X100 (S102)	This is a 5 position rotary switch to set the suppression range to -2.5, OFF, 2.5, 10 or 25 degrees X100.

ITEM NO	CONTROL	DESCRIPTION
4	VERNIER (R101)	This is a 10-turn variable resistor with a calibrated dial. A full clockwise setting of 10.0 gives a suppression of 100% of that indicated by the range switch (S102) above. Lesser settings give proportionally reduced amounts of suppression. This control is fitted with locking knob to prevent inadvertent turning. See section 3.4.3, ZERO SUPPRESSION Control Usage, for an illustrative example:
5	DEGREES (S101)	This is a 2 position rotary switch used to select either degrees F (Counter-clockwise) or degrees C (clockwise).
6	T.C. OPEN (CR101)	This indicator light is a red LED (light emitting diode). When on, it indicates an open input (Thermocouple or T.C.) circuit. An open input circuit also produces a high temperature over-range signal at the amplifier output.
7	POSITION	This 15 turn variable resistor sets pen zero between ±1 full scale from right hand chart edge.

3.3 INTERNAL CONTROLS

The low pass output filter cut-off frequency may be changed by changing capacitor C205 (see Figure 6-3). As shipped, C205 is 2.5 uf and the resultant response is down 3 dB at 5Hz. By simply removing C205, the response is changed to 3 dB down at 200Hz. Other 3 dB frequencies may be obtained by using the following formula to calculate the required value of C205:

$$C205 \text{ (in uf)} = \frac{16}{\text{Frequency at which response is -3dB}}$$

This is an approximate formula and is good only up to about 100 Hz.

See Section IV for factory set internal controls.

3.4 OPERATION

This section lists the logical sequence of steps necessary to measure and record temperatures with the thermocouple amplifier. Do not plug in amplifier module until instructed.

3.4.1 Monitoring an Unknown Temperature

a. See the instruction manual for the Gould 110 Strip Chart Recorder for proper installation, setup, and operation information.

b. Set DEGREES FULL SCALE switch to OFF.

c. Set DEG X 100 switch to OFF.

d. Verify all recorder controls and settings, and switch recorder main power ON.

e. Plug amplifier into rack and plug thermocouple connector into receptacle on back of module. Allow equipment to warm-up for 15 minutes.

f. Select a slow chart speed.

g. If positive temperatures are to be measured, set PEN POSITION control so the pen tracks at the right edge of the chart. For negative temperatures use the left edge.

h. Set the DEGREES (F or C) switch to select either Celsius or Farenheit degrees.

j. Set the sensitivity control full counterclockwise to X1 (detented).

k. Turn the DEGREES FULL SCALE switch to 2500. Left edge of chart now equals 2500 degrees and right edge is zero. Temperature may now be read directly.

1. Turn the DEGREES FULL SCALE switch to best display the particular temperature range being measured.

3.4.2 Variable Sensitivity Control Adjustment

If full scale calibration values in between the six settings possible using the DEGREES FULL SCALE switch are desired, the sensitivity control may be adjusted. It functions as described in FRONT PANEL CONTROLS, Section 3.2. A known temperature must be provided to allow setting this control accurately. A thermocouple simulator, such as the Ectron Model 1100 may be used in lieu of a known temperature.

3.4.3 ZERO SUPPRESSION Control Usage.

At times it may be desirable to suppress (cancel out) unwanted, static portions of a temperature span. The ZERO SUPPRESSION controls allow the reference point on the recorder, typically the chart edge or chart center, to be made some temperature other than zero. This allows a small temperature range to be expanded.

The DEG X100 switch has temperature suppression settings of -250, 250, 1000, and 2500 degrees. These settings are modified by the VERNIER control where-on a setting of 10.0 means the temperature suppressed would be 100% of the DEG X 100 switch setting.

For example, setting the range switch to 1000, i.e. 10 X 100, and the VERNIER to 5.0 turns would result in a suppression of 500 degrees. At 500 degrees the amplifier output would be zero and the recorder would normally be set to the right side of the chart. Continuing with these conditions, if the DEGREES FULL SCALE were set to 50 (sensitivity at X1), the left side of the chart would be 550 degrees. This would allow the temperature range of 500 to 550 degrees to be displayed with maximum possible resolution.

3.5 THEORY OF OPERATION

3.5.1 General

The Thermocouple Amplifier, Model 13-4715-4X, consists of an input amplifier, buffer amplifier, linearizing network, summing amplifier, zero suppression circuit, second summing amplifier with filter, and an output amplifier with variable gain.

The input amplifier is preceded by a compensator which establishes a 0°C reference point and compensates for ambient temperature changes.

A voltage comparator is included in the amplifier to detect an open circuit condition.

3.5.2 Circuit Description

See Figure 3-2 Block Diagram, and schematic 288154 (located after the parts section).

1. Compensator

   The compensator contains a temperature sensitive resistor connected in a bridge network. Potentiometer R247 is adjusted to establish a 0°C reference point for the termocouple. The temperature sensitive resistor compensates for ambient changes to hold the reference point constant.

2. Input Amplifier

   The input amplifier is composed of low noise, low drift, high performance operation amplifier U223 plus associated circuitry. The gain of the amplifier is chosen to be the slope in °C/mv of the straight line approximation of the thermocouple. The output of this amplifier is applied to the X1 inverting buffer U215, the voltage comparator U222, and the linearizing network. The output is also summed into U201 along with the output of the linearizer.

3. Linearizer

   The output of a thermocouple is a nonlinear function of temperature. To arrive at a linear relationship between temperature and voltage, this nonlinear output curve must be combined with one which is equally non linear, but curving in the opposite direction. One method of generating such a curve is to approximate it with straight line segments (see Figure 3-3).

   The curve can be approximated by the formula:

   $°C = (\text{Slope})\ (mV_x) - f\ (B\text{-}mV_x)$ where:

   $\text{Slope} = C_o/mV_o$

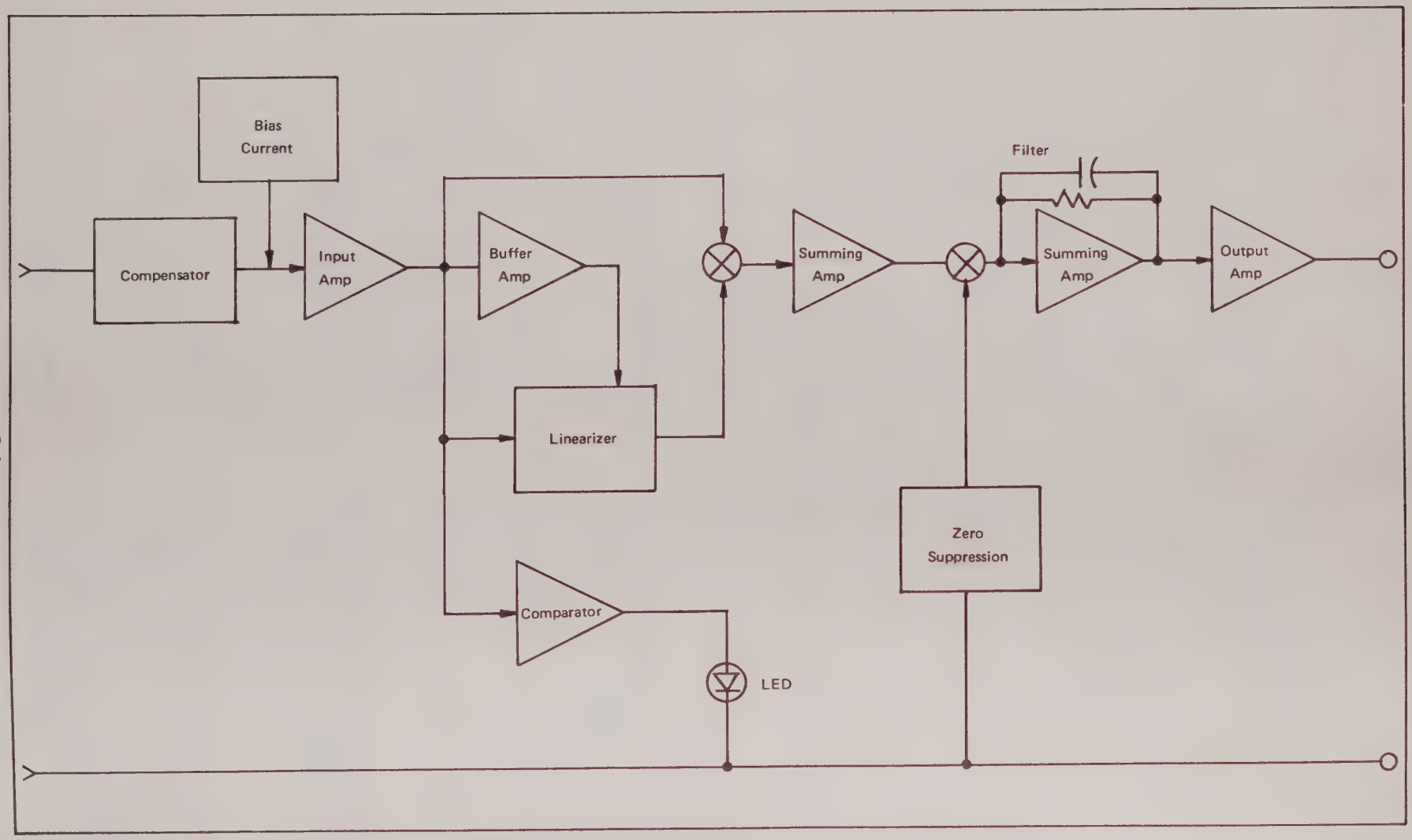


FIGURE 3-2 THERMOCOUPLE AMPLIFIER BLOCK DIAGRAM

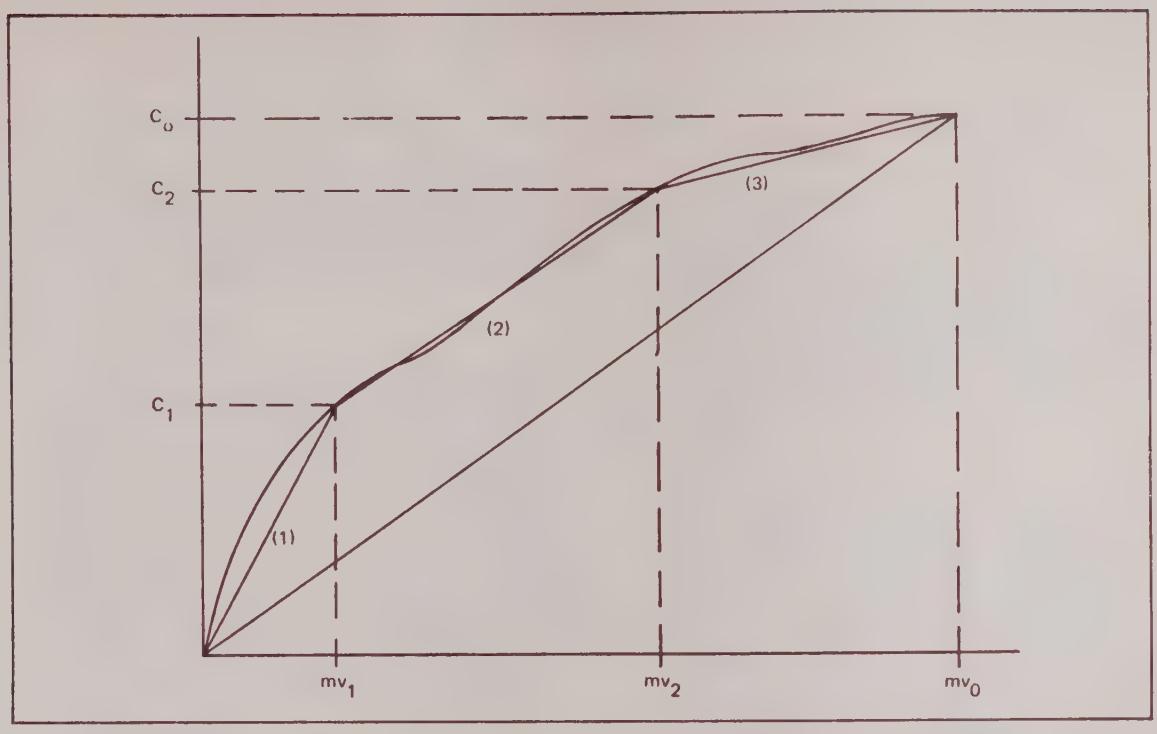


FIGURE 3-3 APPROXIMATING A CURVE WITH STRAIGHT LINE SEGMENTS

mV_x = thermocouple output at temperature C_x.

f = multiplier which changes for each line segment.

B = Constant which changes for each line segment.

The values of f and A for a line segment such as segment 2, shown above can be found by substituting C_1, mv_1 & C_2, mv_2 in the formula and solving the two equations. The "degree" of fit to the curve is determined by the number of line segments used. The line segments are generated by using diodes within the feedback loop of operational amplifiers. (See Figure 3-4). The position on the curve is determined by the output of the thermocouple and a reference voltage.

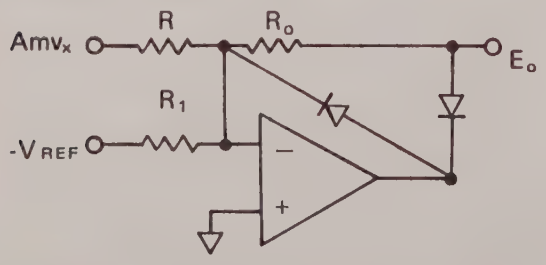


FIGURE 3-4 TYPICAL LINEARIZER CIRCUIT

Amv_x = Thermocouple output amplified by gain A. When $\left|\frac{-V_{REF}}{R_1}\right| > \left|\frac{Amv_x}{R}\right|$ the output, E_o, is 0 volts. When $\left|\frac{Amv_x}{R}\right| > \left|\frac{-V_{REF}}{R_1}\right|$ the output, $E_o = -\frac{R_o}{R} Amv_x + \frac{V_{REF} R_o}{R_1}$. If this is summed into an amplifier with Amv_x the result is: $Amv_x - \frac{R_o}{R} Amv_x + \frac{V_{REF} R_o}{R}$. Rearranging we have $Amv_x + A\frac{R_o}{R}\left(V_{REF}\frac{R}{R_1} \bullet \frac{1}{A} - mV_x\right)$ which has the same form as the approximation for the thermocouple curve.

The linearizer, shown on schematic 288154 sheet 2, is composed of circuits such as those described above. The output of the linearizer is applied to summing amplifier U201.

4. Summing Amplifier U201

The output of the linearizer, along with the output of U223 is summed into U201. The resultant of these voltages is a linear approximation of temperature. The output of U201 is either scaled for °C or °F by resistors R230 & R231 or R232 & R233. °C or °F is selected by front panel switch S101. When °F is selected, an additional 32 mv is summed into U203 (°F = 9/5°C +32).

5. Amplifier U203

U203 is used as a dual purpose amplifier. It is a low pass filter with the bandwidth set by R235 and C205, In addition it is used as a summing amplifier for zero suppression.

6. Zero Suppression

A plus or minus regulated voltage is applied to potentiometer R101 by front panel zero suppression switch S102. The suppression voltage is picked off the wiper of R101 and buffered by operational amplifier U221. The output of U221 is summed into U203 through range resistors R261 through R264. The resistors are selected by zero suppression S102 along with polarity. Full scale temperatures from -250° to +2500° can be suppressed to increase the resolution of the amplifier.

7. Variable Sensitivity

The X1 sensitivity control R288 is in series with R235 in the feedback loop of U203. In the extreme CCW position R288 is shorted out and U203 is a unity gain inverting amplifier. With R288 in the extreme CW position the gain of U203 is increased by a minimum of 2.5. In this manner .4 times the indicated full scale voltages (selected by degrees full scale switch S201) may be displayed.

U208

8. Output Amplifier

The output of U203 is applied (through R288) to the non-inverting amplifier U208. The gain of U203 is selected by the front panel degrees full scale switch S201 to display full scale temperatures from 50° to 2500°.

9. Open Circuit Detector

A small bias current is injected into the input of the input amplifier by means of a voltage applied to R201. Under normal conditions the induced voltage is negligible. Should there be an open circuit, however, the voltage at the input will rise to above 200 millivolts. This voltage is greater than will occur with a thermocouple output. The voltage is amplified and applied to a comparator composed of U222 and resistors R222, R223, R220 and R224.

The threshold for the comparator is set such that, under normal condtions it keeps Q204 in the off state and the LED CR101 remains off. Under an open circuit condition the threshold voltage is exceeded and Q204 turns on and lights the LED.

SECTION IV

CALIBRATION

4.1 GENERAL

In addition to detailed calibration procedures, this section contains paragraphs on troubleshooting and maintenance.

This procedure is broken down into steps by individual adjustments. Under normal conditions, complete calibration should be performed every six months. After repair of the unit or some other change in the electronics, it is necessary only to recalibrate those circuits affected by the change.

NOTE: Performance checks in this section specify limitations based on optimum "new-equipment" values. Should any results be unacceptable, please see the troubleshooting section of this manual or your Gould Service Representative.

4.2 CALIBRATION

4.2.1 General

The Gould Thermocouple Amplifier, Model 13-4715-4X, has been accurately calibrated before shipment from the factory and should give long, trouble free service. Should recalibration be required, it should be performed by qualified technical personnel only, using suitable test equipment as specified below.

NOTE: If a conversion package has been installed to change the amplifier to a different thermocouple type, only the following steps must be done: Section 4.2.4, steps e through m; and Section 4.2.6.

4.2.2 Test Equipment Required

The following is a list of test equipment necessary for calibration.

1. Digital Multimeter: 4½ digit, 0.05% accuracy.
2. Oscilloscope: Gould Model OS330B or equivalent.
3. Precision D.C. Voltage Reference: 0.05% accuracy; Electronic Development Corp. Model VS330H or equivalent.
4. Extender Card and Cable, P/N 788956.
5. Ice Point Reference: Omega Model RC340 or equivalent.

4.2.3 Initial Setup

a. Set front panel controls as follows:

DEGREES FULL SCALE	OFF
DEGREES X100 (SUPPRESSION)	OFF
VERNIER Dial	Remove
°F—°C Switch	°C
Variable Sensitivity	CCW (Detent)

b. Remove right side cover from amplifier (See Figure 4-1).

NOTE: Test points shown in Figure 4-1 are for convenient reference only. Please refer to schematic 288154 at the end of this manual and Board Subassembly Dwg 888193 (Figure 6-3) for test point location.

c. Connect D.C. power source to card edge connector. Plus and minus go to pins C and E, respecitvely.

d. Apply power from Gould 110 Strip Chart Recorder using extender assembly 788956.

e. Remove input connector and check to see that open circuit indicator lights.

f. Remove compensator and connect voltage source set to 0.00 volts to TP-4 (+) and TP-1 (Common).

NOTE: Use low thermal copper clip leads.

g. Connect oscilloscope to TP-7 and check for no oscillations.

h. Allow unit to warm up for 15 minutes.

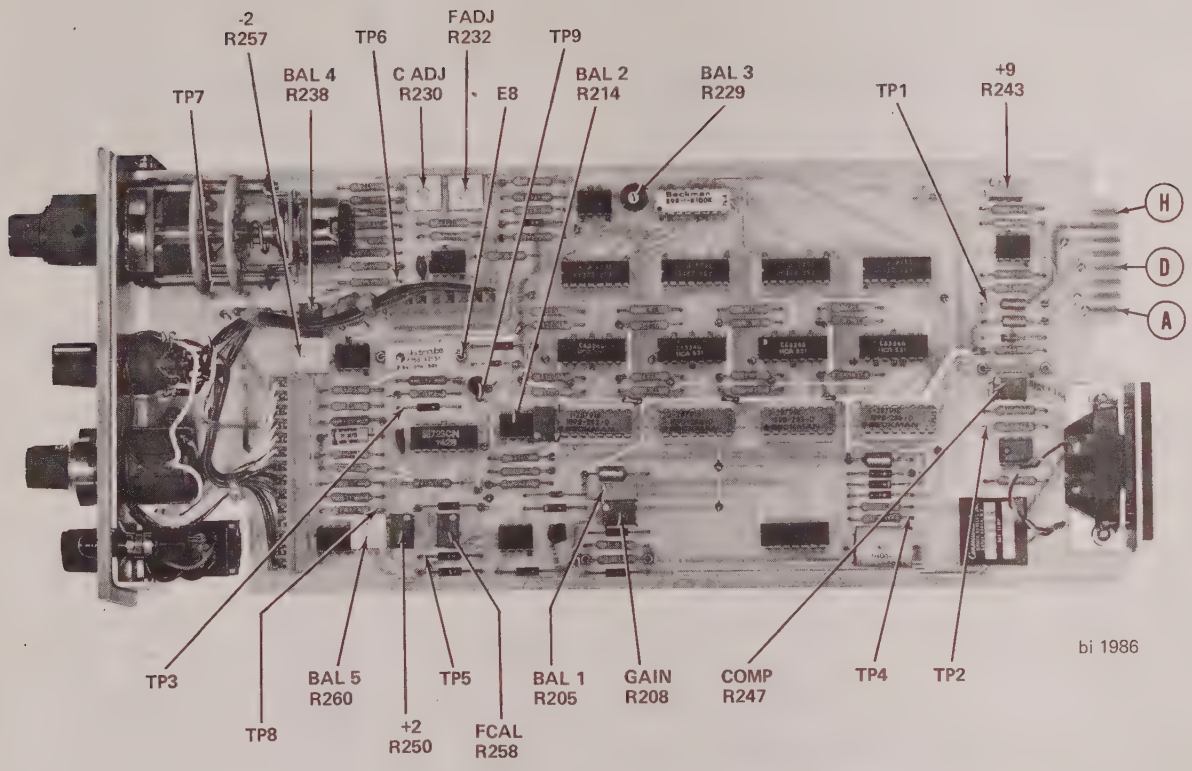
4.2.4 Amplifier Calibration

a. Connect DVM low input to TP-1.

b. Monitor voltage on TP-2. Set to +9 volts ±9mv with R-243 (+9).

c. Monitor voltage on TP-3. Set to +2.0 volts ±1mv with R-250 (+2).

d. Monitor voltage on Pin2 of U-216. Set to -2.0 volts ±1mv with R-257 (-2).



NOTE: RIGHT SIDE COVER REMOVED.

FIGURE 4-1 CALIBRATION COMPONENT LOCATION

e. Monitor voltage on TP-5. Set to 0.0 volts ±200uv with R-205 (BAL1).

f. Monitor voltage on TP-9. Set to 0.0 volts ±200uv with R-214 (BAL2).

g. Monitor voltage on TP-6. Set to 0.0 volts ±300uv with R-229 (BAL 3).

h. 1) Set DEGREES FULL SCALE to 50.

2) Monitor voltage on TP-7. Set to 0.0 volts ±5mv with R-238 (BAL 4).

j. 1) Set °F – °C switch to °F.

2) Monitor voltage on TP-7. Set to 640mv ±10mv with R-258 (F CAL).

k. 1) Set DEGREES FULL SCALE to 1000.

2) Set °F–°C switch to °C.

3) Monitor voltage on TP-5. Apply the voltage specified below for the Thermocouple type and adjust R-208 (GAIN) for the correct reading ±300uv.

TYPE	INPUT in MILLIVOLTS	OUTPUT in VOLTS
J	42.283	0.750
K	41.269	1.000
T	20.869	0.400
E	76.358	1.000
R	10.503	1.200
S	9.585	1.117

l. Monitor voltage on TP-7. Set to voltage specified below with R-230 (C ADJ) for the correct reading ±2mv.

TYPE	OUTPUT in VOLTS
J	0.750
K	1.000
T	0.400
E	1.000
R	1.000
S	1.000

m. 1) Set °F–°C Switch to °F.

2) Monitor voltage on TP-7. Apply the voltage specified below for the Thermocouple type and adjust R-232 (FADJ) for the correct reading ±2mv.

TYPE	INPUT in MILLIVOLTS	OUTPUT in VOLTS
J	29.515	1.000
K	22.251	1.000
T	20.801	0.750
E	40.056	1.000
R	4.885	1.000
S	4.609	1.000

4.25 Suppression Voltage

a. Set DEGREES FULL SCALE to 1000.

b. Set °F–°C Switch to °F.

c. Monitor voltage on TP-7.

d. Set SUPPRESSION Switch to +10.

e. Rotate suppression potentiometer fully clockwise.

f. Set vernier turns counting dial to 10.0 and lock. Place dial on shaft and secure in place with set screw.

g. Apply the voltage specified below for the Thermocouple type. Unlock and set vernier turns counting dial to specified setting and adjust R-260 (BAL 5) for 0.0 volts ±2mv.

TYPE	VERNIER SETTING	INPUT in MILLIVOLTS
J	10.0	29.515
K	10.0	22.251
T	7.5	20.801
E	10.0	40.056
R	10.0	4.885
S	10.0	4.609

4.2.6 Compensator Calibration

a. Remove voltage source. Reinstall compensator and connect thermocouple through input connector.

b. Insert thermocouple in ice point reference and allow to stabilize for 5 minutes.

c. Monitor voltage on TP-6. Set °F–°C switch to °C. Set to 0 volts ±300uv with R-247 (Comp).

d. Monitor voltage on TP-7. Readjust R-238 (BAL 4) if necessary to obtain 0V ±5mv.

e. Set °F–°C Switch to °F.

f. Monitor voltage on TP-7. Readjust R258 (F CAL) if necessary to obtain 640 mv ±10mv.

g. Remove power, test equipment and extender assembly.

h. Install amplifier in recorder.

j. System is ready for use.

4.3 SYSTEM CALIBRATION CHECK (PREAMP PLUS RECORDER)

4.3.1 Gain Accuracy

a. Set preamplifier controls as follows:
DEGREES FULL SCALE — OFF
°F – °C Switch — °C
DEG X100 — OFF

b. Turn recorder on and run at 2 in./min. Use pen position to set trace to left zero.

c. Apply 0° to the thermocouple (Can use an ice point reference). Check pen zero for left chart edge.

d. Turn DEGREES FULL SCALE control to 1000.

e. Turn DEG X100 switch to +1000 and set VERNIER dial successively to 2.5, 5.0, 7.5 & 10.0.

f. The readings on the chart should be:
2.5 – 25% FULL SCALE ±.5%
5.0 – 50% FULL SCALE ±.5%
7.5 – 75% FULL SCALE ±.5%
10.0 – 100% FULL SCALE ±.5%

g. Turn DEG X100 switch to OFF. Set DEGREES FULL SCALE switch to 50 & set pen to right chart edge.

h. Set °F—°C to °F & read 32° F ±1.5°.

4.3.2 Noise

a. Short the input to the preamp using copper wire and set the chart speed to 2 in./min. Position the pen on the zero line. Run the chart at 8 in./min. for approximately 1 inch.

b. The trace width should be less than 1% of full channel width.

4.4 TROUBLESHOOTING

Troubleshooting may be performed in conjunction with the schematic (located after the parts section) and the bench equipment listed in paragraph 4.2.2. When the amplfier is used with a Gould 110 Strip Chart Recorder, refer to the troubleshooting table in Section V of the recorder manual.

4.5 MAINTENANCE

4.5.1 General

Maintenance on the amplifier is limited to cleaning only.

CAUTION:

a. BEFORE ATTEMPTING TO CLEAN AMPLIFIER TURN OFF POWER AND REMOVE FROM ENCLOSURE.

b. AVOID USE OF CHEMICAL CLEANING AGENTS WHICH MIGHT DAMAGE PLASTIC OR PRINTED SURFACES. DO NOT USE CHEMICALS WHICH CONTAIN TOLUENE, CELLUSOLVE ACETONE OR SIMILAR SOLVENTS.

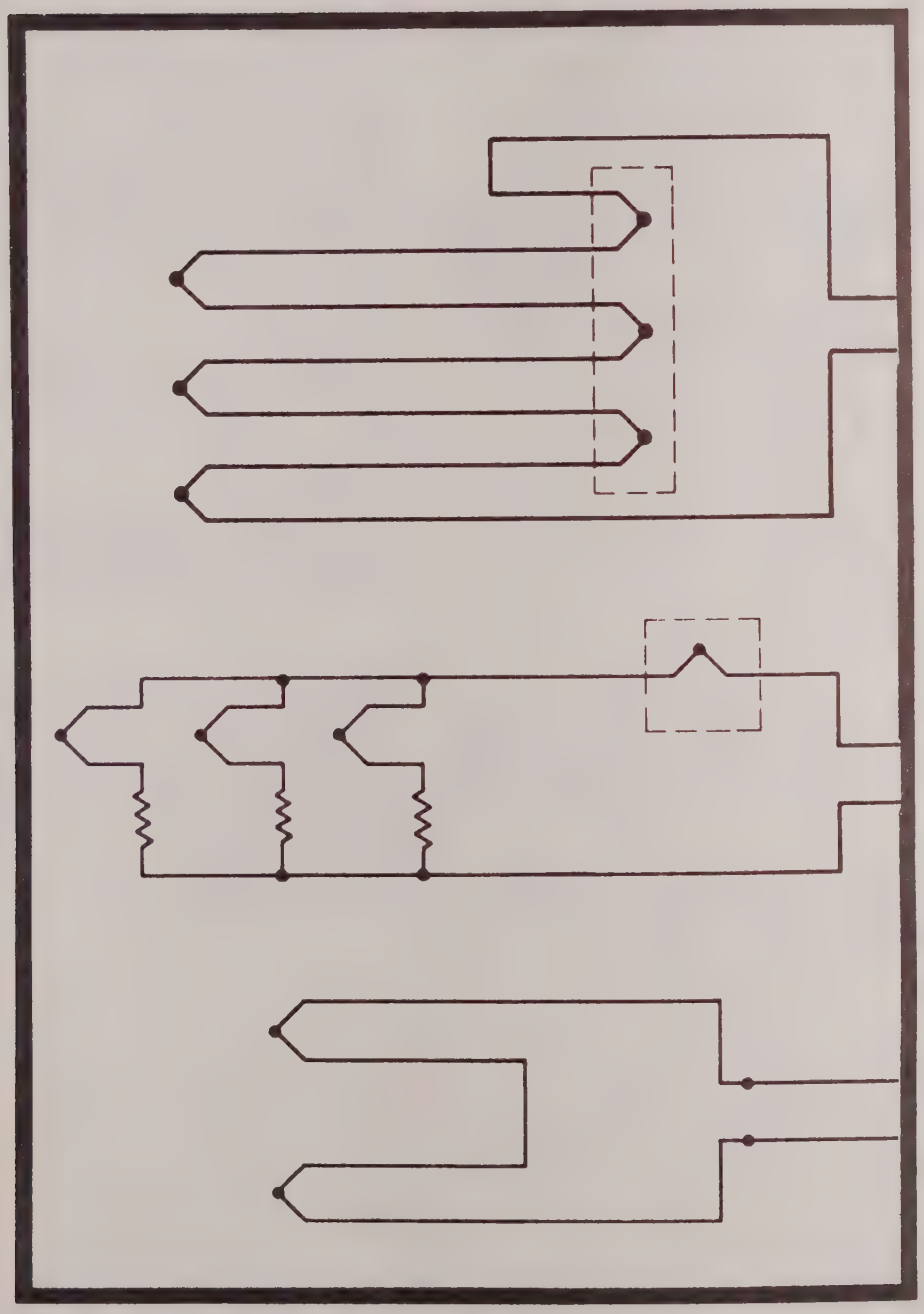
4.5.2 Exterior

Remove loose dust with a soft cloth or small paint brush. Dirt which remains can be removed with a soft cloth dampened in mild detergent and water solution. DO NOT USE ABRASIVE CLEANERS.

4.5.3 Interior

Dust in the interior should be removed occasionally due to its electrical conductivity under high humidity conditions. Blow off accumulated dust with dry low pressure air. Remove any dirt which remains with a soft paint brush or a soft cloth dampened in a mild detergent and water solution. Use a cotton-tipped application for cleaning in narrow spaces and/or printed circuit boards.

THEORY AND PRACTICE OF TEMPERATURE MEASUREMENT WITH THERMOCOUPLES



THERMOELECTRIC EFFECTS

A discovery by T. J. Seebeck almost 150 years ago opened the way for modern thermoelectric thermometry. In 1821, Seebeck observed that an electric current flows in a closed circuit of two dissimilar metals when one of the two junctions is heated with respect to the other.

In such a thermocouple circuit, the current continues to flow as long as the two junctions are at different temperatures. The magnitude and direction of the current are functions of the temperature difference between the junctions and of the thermal properties of the metals used in the circuit. This phenomenon, Figure 1A, is known as the **Seebeck effect.**

It follows that the tendency for current to flow in a thermocouple circuit under these circumstances will develop into an electromotive force, or emf, if the thermocouple is opened somewhere along the circuit, Figure 1B.

In fact, a thermocouple circuit will accurately generate a measurable, low voltage output that is almost directly proportional to the temperature difference between the "hot" junction and the "cold" junction. A unit change in this temperature difference will produce some net change in emf.

Thermoelectric thermometry makes use of the known relationship between a difference in junction temperatures and the resulting emf developed by a thermocouple circuit. In practice, the temperature of one junction (the reference junction) is held at a constant, known value. With suitable precautions, the temperature of the other junction (the measuring junction) can be determined accurately by measuring the thermocouple circuit emf and referring to calibration tables for the particular thermocouple materials.

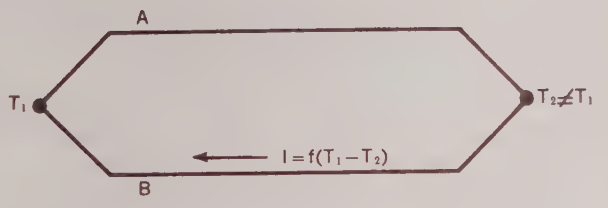


Figure 1A. Diagram illustrates the **Seebeck effect,** whereby an electric current, I, will flow in a closed circuit of two dissimilar metals, A and B, when the two junctions are at different temperatures, T_1 and T_2.

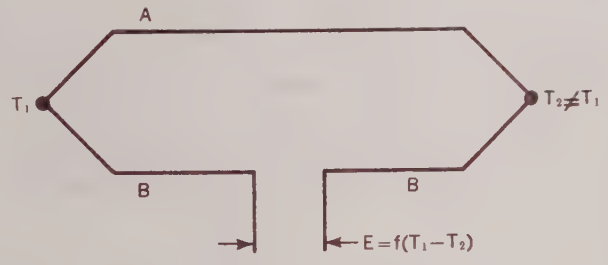


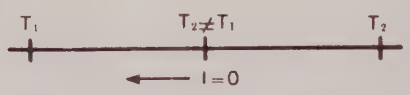
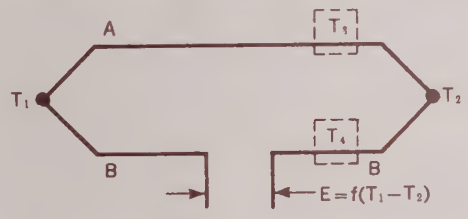
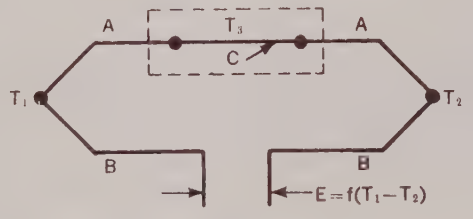
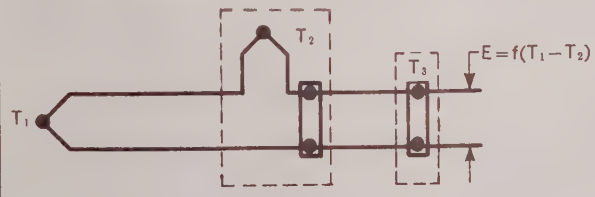
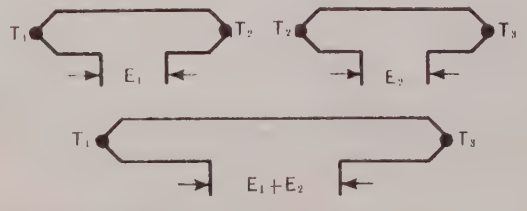
Figure 1B. The basis for modern thermoelectric thermometry is the definite relationship between a difference in junction temperatures, T_1 and T_2, and the resulting emf, E, developed by a thermocouple circuit.

THERMOELECTRIC LAWS

Much experimentation with thermocouple circuits has led to the formulation of three empirical "laws" which are fundamental to the accurate measurement of temperature by thermoelectric means. Each law is stated and illustrated in Table 1, and its significance given in terms of an actual thermoelectric temperature measuring installation.

TABLE I

Basic Thermoelectric Laws and Their Significance in Thermoelectric Instrumentation Systems

The Basic Thermoelectric Law	Practical Implications for Thermoelectric Thermometry
1. The Law of Homogeneous Circuits	
"An electric current cannot be sustained in a circuit of a single homogeneous metal, however varying in section, by the application of heat alone." 	As long as the metal of each wire in a thermocouple is homogeneous, the emf generated at the junction will not be affected by the temperatures of the lead wires even though a temperature distribution exists along the wires. 
2. The Law of Intermediate Metals	
"The algebraic sum of the thermoelectromotive forces in a curcuit composed of any number of dissimilar metals is zero if all the circuit is at a uniform temperature." 	Any measuring device or lead wire can be added to the circuit without affecting the accuracy as long as the new junctions are at the same temperature. Also permits soldering or brazing thermocouple junctions. 
3. The Law of Successive or Intermediate Temperatures	
"If two dissimilar homogenous metals produce a thermal emf of E_1 when the junctions are at temperatures T_1 and T_2, and a thermal emf of E_2 when the junctions are at temperatures T_2 and T_3, the thermal emf generated when the junctions are at temperatures T_1 and T_3 will be $E_1 + E_2$. 	This law permits the determination of measuring junction temperature from a calibration chart based on a certain reference junction temperature, when the reference junction is at a different, but known, temperature from the chart basis temperature. It also makes feasible the use of oven controlled and electrically simulated reference junctions described elsewhere in this report.

Summary

By combining these three basic thermoelectric laws, it is seen that: (1) the algebraic sum of the thermoelectric emfs generated in any given circuit containing any number of dissimilar homogeneous metals is a function only of the temperatures of the junctions and, (2) if all but one of the junctions in such a circuit are maintained at some reference temperature, the emf generated depends only upon the temperature of that junction and can be used as a measure of its temperature.

THERMOCOUPLE JUNCTIONS & MATERIALS

The junctions of thermocouples may be formed by welding, brazing, soldering, or mechanical joining. Considerations in selecting a joining technique include joint strength, contact resistance, environmental conditions (including operating temperature), and compatibility of the joining method with the thermocouple materials.

Although many materials can be combined to produce a thermoelectric effect, certain pairs have become more widely used than others. National Bureau of Standards Circular No. 561 gives reference tables for the thermocouple material combinations that are most commonly used in the United States. Some of these thermocouples are listed in Table 2 and described in greater detail below.

Table 2—Common Thermocouples

ISA* Type	Conductor		Temperature Range, F	Limits of Error		Application Notes
	Positive	Negative		Standard	Special	
J	Iron	Constantan	32 to 530 530 to 1400	± 4F ± ¾%	± 2F ± ⅜%	Reducing atmosphere recommended
T	Copper	Constantan	—300 to —75 —150 to —75 —75 to +200 200 to 700	— ± 2% ± 1½F ± ¾%	± 1% ± 1% ± ¾F ± ⅜%	Excellent in oxidizing and reducing atmosphere within its temperature range.
K	Chromel	Alumel	32 to 530 530 to 2300	± 4F ± ¾%	± 2F ± ⅜%	For oxidizing atmosphere.
E	Chromel	Constantan	32 to 600 600 to 1600	± 3F ± ½%	— —	Highest output of common thermocouples
S	Platinum 10% Rhodium	Platinum	32 to 1000 1000 to 2700	± 5F ± ½%	± 2.5F ± ¼%	Laboratory standard, highly reproducible
R	Platinum 13% Rhodium	Platinum	32 to 1000 1000 to 2700	± 5F ± ½%	± 2.5F ± ¼%	Oxidizing atmosphere recommended

*Instrument Society of America

Type J: Iron / Constantan

This is the most widely used type because of its low cost and high thermoelectric output. It is adaptable to both oxidizing and reducing atmospheres. The thermoelectric emf of Type J thermocouples increases rather uniformly from about 26 μv/degree C at −190 degrees C to 63 μv/degree C at 800 degrees C.

Type T: Copper/Constantan

This type of thermocouple gives dependable results at temperatures down to −200 degrees C. With suitable precautions, it can be used down to −260 degrees C. Its upper limit is about 350 degrees C, being limited by the rapid oxidation of copper at higher temperatures.

The thermoelectric emf of Type T thermocouples increases fairly uniformly from about 15 μv/degree C at −200 degrees C to 60 μv/degree C at 300 degrees C. This type is available in small wire sizes (20 to 30 B & S Gauge) and therefore can be installed in confined spaces. The copper wire in this type of thermocouple is more homogeneous than the iron wire in Type J thermocouples.

Type K: Chromel/Alumel

The thermoelectric output of the Type K thermocouple is fairly constant at about 40 μv/degree C over the range from 250 to 1000 degrees C. The result is a nearly linear temperature/emf characteristic. The most important application for Type K thermocouples is in the temperature range from 700 to 1260 degrees C in nonreducing atmospheres.

Type E: Chromel/Constantan

This type of thermocouple has very good voltage stability over its specified range, and features the highest thermoelectric output of all the commonly used thermocouples. The output increases from 68 μv/degree C at 100 degrees C to 81 μv/degree C at 500 degrees C and then decreases to 77 μv/degree C at 900 degrees C. This thermocouple is especially useful for differential temperature measurements, since its large output emf makes for easy amplification.

Type S: Platinum/Platinum—10% Rhodium

The Type S thermocouple has excellent mechanical and chemical properties with low resistivity and excellent homogeneity. Its main applications are for precise temperature measurement in the range from 0 to 1500 degrees C. This thermocouple is specified as the means for interpolating temperature between 630.5 and 1063.0 degrees C on the International Temperature Scale.

The thermoelectric output of a Type S thermocouple is about 6 μv/degree C between 0 and 100 degrees C. It will match its temperature conversion table within ±0.25% of measured emf. Because of its low output, however, this type of thermocouple should not be used for measuring subzero temperatures.

Type R: Platinum/Platinum–13% Rhodium

Output of the Type R thermocouple is slightly higher than that of the Type S. The Type R thermocouple is less expensive because of the lower platinum content of one wire. This thermocouple is suited for precise industrial (as opposed to laboratory) applications over the temperature range from 0 to 1500 degrees C.

EXTENSION WIRES

In most industrial applications, temperature recorders are located some distance from the measuring junctions of thermocouples. The reference junctions are usually at or near the recorders. Connections between the thermocouples and the recorders are made with extension wires. These wires must be properly selected so as not to introduce error-causing junctions in the measuring circuits.

Usually, the extension wires for a thermocouple are made of the same materials as the thermocouple. An exception is in the case of platinum/platinum-rhodium thermocouples for industrial applications, because of the high cost of these materials. Low-cost extension wires of copper and copper-nickel alloy are available that closely match the characteristics of platinum/platinum-rhodium thermocouples.

Extension wire is available as insulated, matched pairs with both the conductors and the insulation color coded. In wire of rip-cord construction, the parallel conductors may be easily separated for fast wiring. Alternately, twisted conductors are available that provide inherent rejection of electromagnetic interference. The pairs of conductors––either parallel or twisted––may have an outer jacket produced by extrusion, wrapping, or braiding.

A number of insulations are available for the individual conductors and the outer jackets of thermocouple extension wires. These are selected according to the requirements of the application, such as resistance to high or low temperatures, moisture, corrosion, chemical agents, or abrasion; small permissible outside diameter; flexibility for ease of routing; etc.

Typical insulations for conductors include polyvinyl chloride, polyethylene, nylon, Teflon, rubber, asbestos, and fiberglass. Outer jacket materials may be any of the previous materials plus cotton braid, Mylar tape, or Mylar-aluminum tape with a drain wire.

When required, metal coverings over jacketed extension wires provide additional strength and rejection of electrostatic interference. Such coverings include overbraids of tinned copper, steel, and stainless steel; spiral metal armor; and lead sheathing.

Thermocouple extension cables combine two or more pairs of insulated extension wires in a common jacket, with or without electrostatic shielding and drain wire. Up to 60 pairs of extension wires may be incorporated in a cable, with 4 to 24 pairs being most common.

The following rules should be observed in selecting and installing thermocouple extension wires and cables:

- Use only the recommended conductors for the thermocouple.
- Connect negative-to-negative and positive-to-positive, as identified by color code.
- Specify proper insulation for conductors and jackets, to meet environmental conditions.
- Avoid splices in the conductors of extension wires and cables.
- Install unshielded extension wires and cables in grounded conduits––and never in proximity to power lines.
- Ground the outer metal sheath or drain wire of shielded extension wires and cables.

REFERENCE JUNCTIONS

Since the emf generated by a thermocouple circuit is a function of the **difference** in temperature between the measuring junction and the reference junction, it is important that the reference junction be maintained at a **constant, known** temperature. This can be accomplished with (1) a temperature controlled oven, (2) an ice bath, or (3) an electrical means of simulating a known temperature.

Temperature Controlled Ovens

With a single temperature controlled oven, the reference junction is usually held at 150 degrees F. Allowance must be made for the fact that the reference junction is at this temperature, and not 32 degrees F; however, for each type of thermocouple, the correction is readily determined. The accuracy of this type of reference is dependent upon the temperature control of the oven and is nominally ±1 to ±5 degrees F.

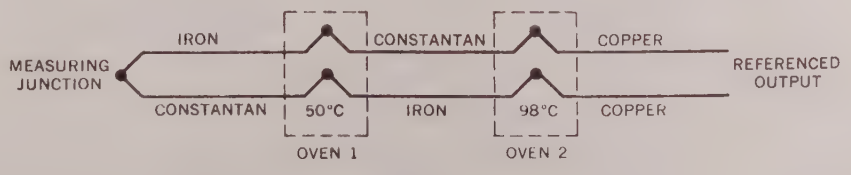


Figure 2

A typical double oven arrangement to simulate an ice point reference temperature. Regulated temperatures of the individual ovens are functions of the types of thermocouple materials.

A double oven reference, Figure 2, uses dual temperature controlled ovens to automatically simulate an ice point reference temperature. The two ovens are maintained at different temperatures, and the thermocouples in each oven are oppositely polarized to cancel the emf's they generate. With the proper combination of oven temperatures and reference thermocouples, it is possible to simulate 32 degrees F (0 degrees C) at the reference.

Ice Bath

The ice bath reference consists of a container of cracked, melting ice with the reference junction completely immersed in the liquid. This arrangement can maintain a reference temperature of 32 degrees F (0 degrees C) within ±1 degree F.

A well made ice bath kept in an insulated dewar will maintain an extremely stable temperature for a period of time. This easily repeatable standard gives a reliable reference temperature as long as the ice and water are in physical equilibrium. As melting occurs, the ice may rise in the dewar, giving the appearance of an acceptable bath, whereas the thermocouple junction at the bottom of the dewar is in water which is several degrees above 32 degrees F. Thus the common ice bath, while inexpensive and readily made, has its limitations.

Electrical Temperature Simulation

This is by far the most convenient and popular means of cold junction reference. The most common type of electrical reference is the basic bridge circuit, Figure 3.

In this configuration, R_2 is a temperature-sensitive component that is thermally bonded to the cold junction thermocouple. The resistance-temperature curve of R_2 matches the emf-temperature characteristic of the thermocouple material. The voltage change across R_2 is equal and opposite to the cold junction thermal voltage over a wide ambient temperature range, resulting in virtually error-free compensation. The circuit also produces an offset voltage equivalent to the required reference temperature. This results in the simulation of a reference temperature at the cold junction end of the thermocouple circuit.

This type of reference temperature simulation is well adapted to zero suppression of a large temperature. By specifying the reference temperature at or near the temperature to be recorded, small temperature changes can be recorded. The accuracy of this type of reference junction is about ±0.5 degree F. It can be made very small and requires little power.

MULTIPLE THERMOCOUPLE CIRCUITS

Temperature measuring systems often use more than one thermocouple to achieve special effects and/or economy of installation. Some representative multiple thermocouple circuits are shown and described below.

Series-Connected Thermocouples

Figure 4 illustrates the series connection of thermocouples for averaging of temperatures. The measuring thermocouples are connected in series, using extension wires of the proper materials. The emf developed at the output terminals of this circuit is the sum of the emf's developed by the individual thermocouples. Consequently, instruments used with this type of circuit must be calibrated for the total emf of all the thermocouples, and electrical cold junction compensation (if used) must be adjusted for the greater millivolt changes resulting from changes in ambient temperature.

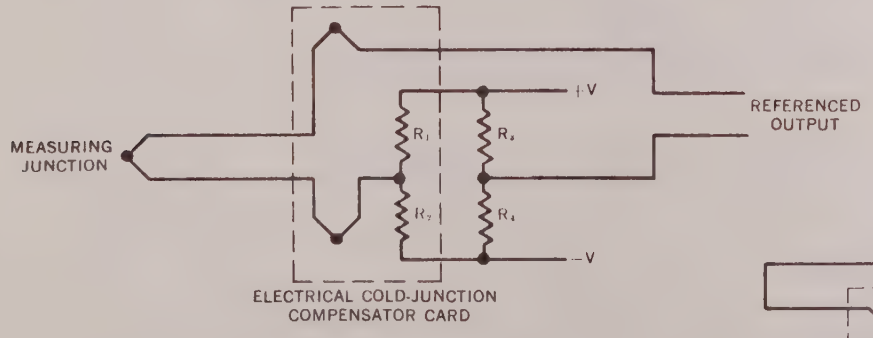


Figure 3
Electrical cold-junction compensation is a convenient and popular method of simulating a reference temperature. This method also permits zero suppression for improved linearity and sensitivity to small temperature changes.

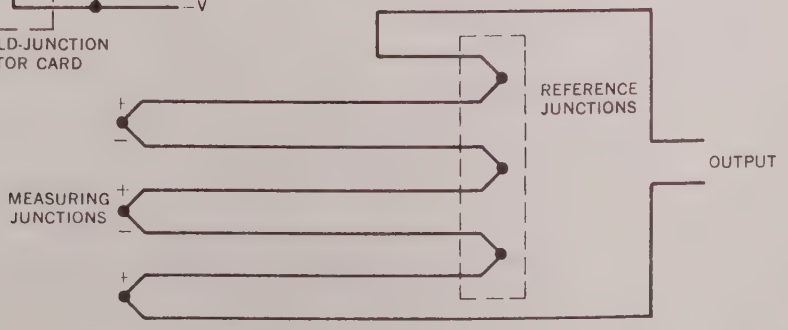


Figure 4
Connecting thermocouples in series gives an average temperature result. Output emf is the sum of the emf's developed by each thermocouple in the series circuit.

An advantage of this circuit is the large emf it generates for a given temperature or combination of temperatures. Limitations of the circuit include the need for special calibration, and the fact that care must be taken to prevent grounding of, or interconnections between, any of the measuring thermocouples.

Parallel-Connected Thermocouples

Parallel connection of thermocouples, Figure 5, also gives an average-temperature result. In this circuit, the net emf developed at the output is the average of the potential drop across each branch rather than the average of all the emf's as in a series circuit.

Resistors, R, may be placed in the circuit of each measuring thermocouple. These resistors have a relatively high value (typically 500 ohms) in relation to the resistance of the thermocouples. The purpose of these resistors is to minimize the effects of currents that circulate among the thermocouple branches when the temperatures sensed by the measuring thermocouples are different. Factors establishing the value of resistance R are the sensitivity of the recorder/amplifier and the number of thermocouples in the circuit.

Advantages of the parallel-connected thermocouple circuit include: (1) average temperature can be determined directly from standard tables for the type of thermocouples used, and (2) electrical cold junction compensation is not affected by the number of thermocouples used.

Differentially-Connected Thermocouples

The difference between two temperatures can be sensed and recorded with a differential thermocouple circuit, Figure 6. It is interesting to note that this circuit does not require a reference junction. Instead, one measuring junction performs as a "hot" junction and the other as a "cold" junction.

Another unique feature of this circuit is that a similar metal joins and becomes a part of each thermocouple; thus, the output leads are of the same material. This means that a third metal (the extension wires) can be of any conventional metal—such as copper—without affecting the accuracy of measurement, provided the points of connection are at the same temperature.

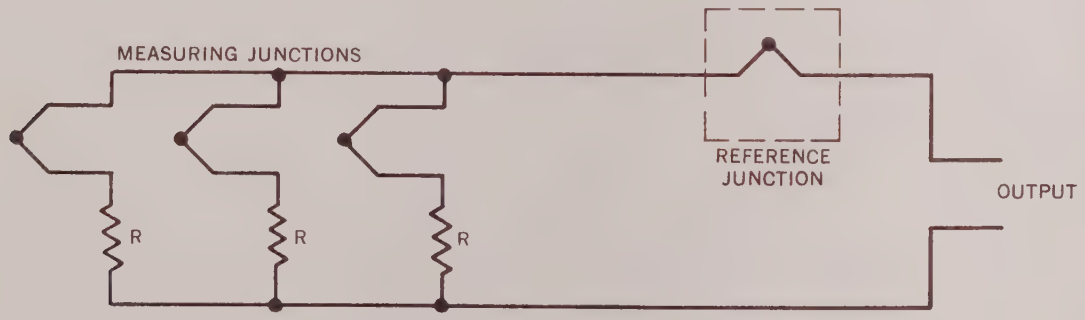


Figure 5
Parallel-connected thermocouples also give an output representing average temperature. Standard thermocouple conversion tables are applicable with this type of circuit.

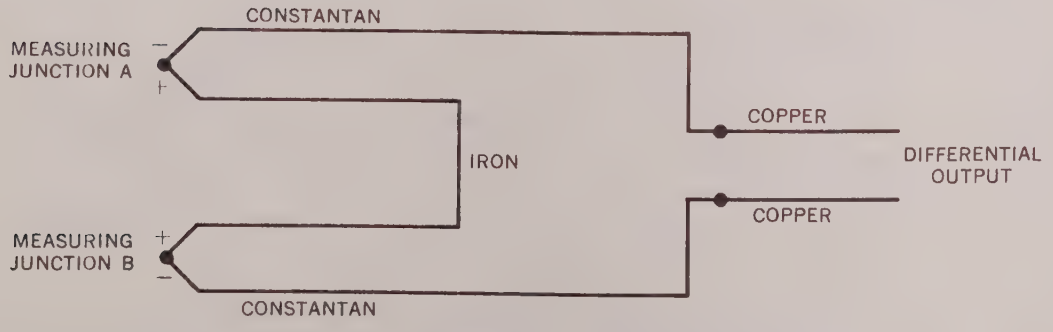


Figure 6
Differential thermocouple circuit measures the difference between two temperatures. This type of circuit does not require a reference junction.

TEMPERATURE MEASUREMENT

Figure 7 illustrates the emf output versus temperature in degrees F for each of the major types of thermocouples. Two important facts should be noted from the curves: (1) the sensitivity (slope) of each curve is different and (2) none of the curves has a perfectly linear rate of change of emf output per degree F. This means that each type of thermocouple has a unique, nonlinear response to temperature.

Most recording or display devices are linear; that is, their output (displacement of a pen or needle, or digital display value) varies directly with input. Thus, a problem arises in correlating recorder or display device output with actual temperature.

One solution is to incorporate a linearization network in a readout device. The network compensates for the nonlinearity characteristics of a particular type of thermocouple over a limited temperature range.

This creates a special purpose system, with limited utility, that will directly indicate or record temperatures sensed by a specific type of thermocouple over a given temperature range. The type of thermocouple may not be changed, nor may the instrumentation be used for any other purpose. This type of equipment is most applicable for installations where temperatures, over a limited range, must be read directly and repeatedly over long periods.

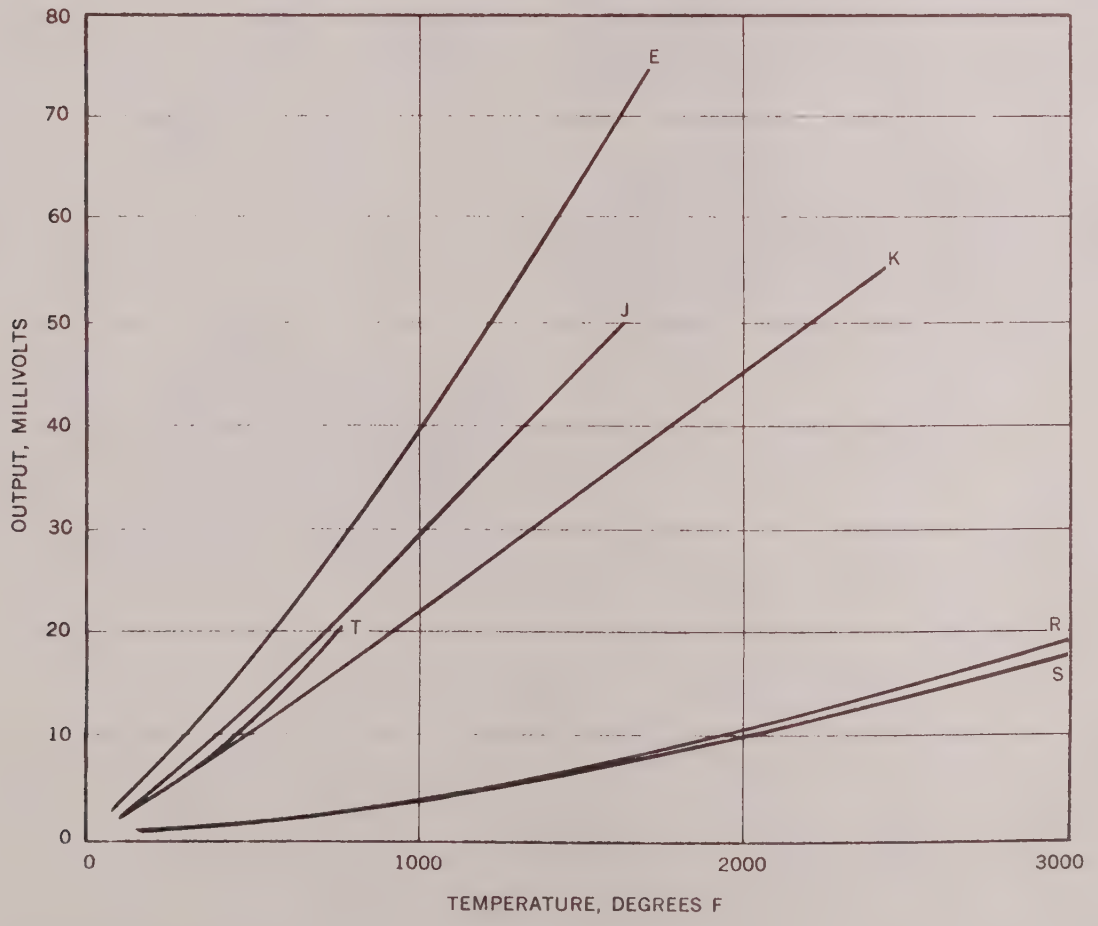


Figure 7
Curves illustrate the emf versus temperature characteristics of six major types of thermocouples. Note that the various thermocouples vary in sensitivity, and that no thermocouple has a perfectly linear emf versus temperature relationship.

A more economical solution is often to use a general purpose recorder or display device in conjunction with any suitable type of thermocouple. The output of the recorder or display device, in millivolts output from the thermocouple circuit, is easily converted to measured temperature by means of conversion tables found in National Bureau of Standards Circular 561.

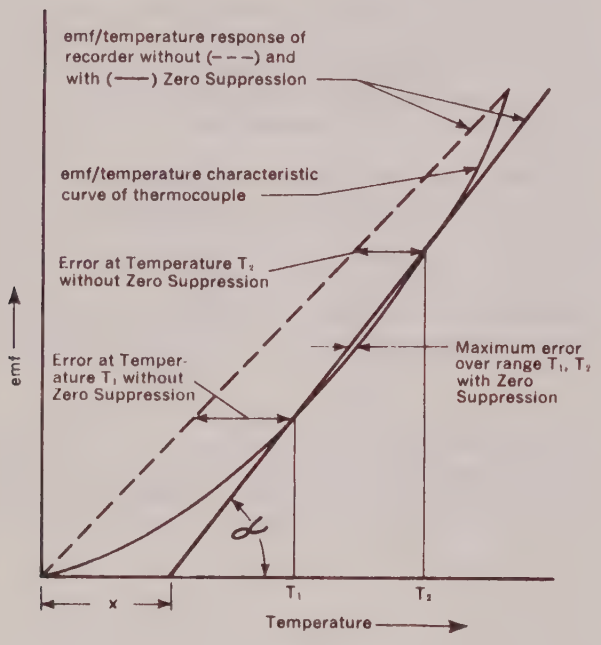

emf/temperature response of recorder without (– – –) and with (——) Zero Suppression
emf/temperature characteristic curve of thermocouple
Error at Temperature T₂ without Zero Suppression
Error at Temperature T₁ without Zero Suppression
Maximum error over range T₁, T₂ with Zero Suppression
emf
x
T₁
T₂
Temperature

Figure 8

Zero suppression can greatly improve the linearity of recorder measurements over a limited temperature range. In this example, the emf/temperature response of the recorder has been adjusted to closely match that of the thermocouple in the range from T_1 to T_2. The angle **alpha** is a function of amplifier gain; and the effective distance is determined by the amount of zero suppression. Other portions of the thermocouple curve can be matched by adjusting these parameters.

This arrangement retains the flexibility of the basic recorder or display device, and permits any thermocouple to be used. For example, a temperature measuring setup can be made for a particular purpose, and the setup can be broken down when that purpose has been served. The instrumentation can then be released for other uses.

Another option available with a general purpose recorder setup is the use of zero suppression, Figure 8. This permits the recorder to "see" only a preselected portion of the emf/temperature characteristic curve of the thermocouple. The result is greatly improved linearity—often to the point where temperatures can be read directly from the emf trace without reference to conversion tables. Also, small temperature changes within the preselected range are easily recorded.

General purpose recorders are suitable for permanent, as well as temporary, temperature measuring installations. For example, operators can be trained to make decisions on the basis of millivolt readings, as well as temperature readings, that are out of limits. Conversions, where required, need not be made on the shop floor—chart traces can be analyzed at a central point, perhaps with a special scale devised for the purpose.

The general purpose instrumentation approach is particularly adaptable to research and development, and to manufacturing where products and processes change frequently. If a "permanent" installation becomes obsolete, the basic equipment can be used to record other phenomena, including but not restricted to temperature.

GOOD THERMOCOUPLE PRACTICE

Assuming that a thermocouple and its extension wire have been properly selected for the application, there are still several ways that errors can be introduced at installation and in later service. Following are some precautions to observe:

AVOID COLD WORKING. Excessive deformation of thermocouple wire can adversely affect accuracy of temperature measurement. Avoid severe bending, flexing, or hammering of such wire. If cold working occurs from any cause, consider heat treatment to remove its effects.

WATCH EXTRANEOUS JUNCTIONS. New, unwanted thermocouple junctions are created every time dissimilar metals are joined, as when connecting lead wires in a thermocouple circuit and when connecting the circuit to a recorder. Such junctions may even exist within the instrument. The solution is to maintain a uniform ambient temperature in the vicinity of extraneous junctions, and at the measuring device.

PROVIDE ADEQUATE PROTECTION. If high temperatures, corrosive environments, mechanical or thermal shock, or other adverse conditions will be encountered, select a thermocouple designed to resist these effects, such as a metal sheathed thermocouple.

USE LARGEST PRACTICAL WIRE SIZE. Heavy gauge thermocouples have greater long-term stability at high temperatures than thermocouples of lighter gauge. The largest practical wire size should be used, consistent with other requirements such as rapid response, flexibility, and available space.

LOCATE THERMOCOUPLES PROPERLY. The thermocouple should be placed so that the measured temperature is representative of the equipment or medium under study. For example, stagnant areas or exposure to direct flame impingement should be avoided. If the thermocouple is immersed in a fluid (gas or liquid), the depth of immersion should be sufficient to minimize heat transfer away from the measuring junction. A minimum depth of ten times the outside diameter of the protection tube is considered adequate to prevent serious temperature errors on the low side. Also to be considered is the possibility of radiation heat transfer to a bare thermocouple junction from the environment. In this case, radiation shields can be effective.

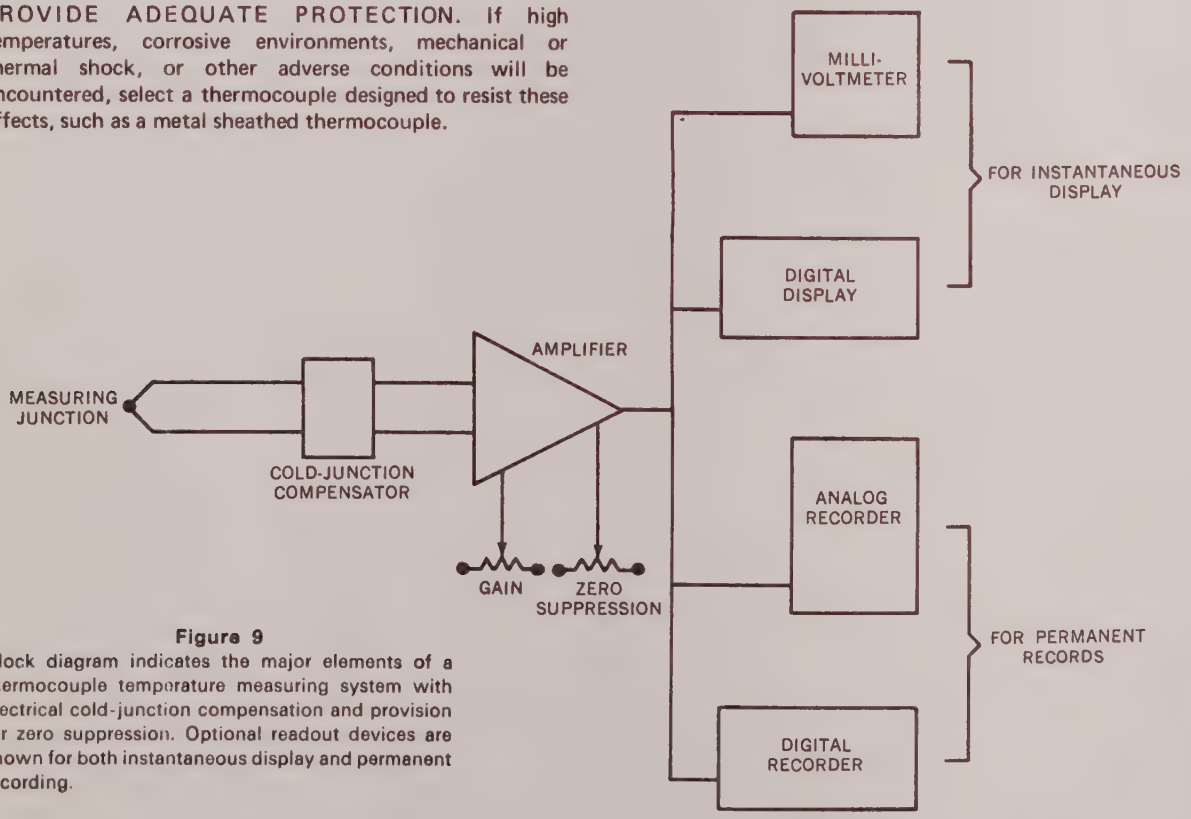


Figure 9
Block diagram indicates the major elements of a thermocouple temperature measuring system with electrical cold-junction compensation and provision for zero suppression. Optional readout devices are shown for both instantaneous display and permanent recording.

SECTION VI

PARTS IDENTIFICATION

6.1 GENERAL

This instrument has been accurately calibrated and adjusted before shipment from the factory and should give long, trouble-free service. For servicing beyond the scope of the instructions contained in this manual or the technical equipment available, contact your nearest Gould Service Engineer listed on the warranty card shipped with the instrument.

The following parts lists and schematic diagrams are designed to assist in servicing and repairing the instrument.

NOTE: Check to be sure the schematic number and revision letter stamped on the rear of the instrument agree with the number and revision letter on the schematic contained in this section.

To assure prompt and satisfactory delivery of replacement parts, include the following with the purchase order:

1. Name, model number, and serial number of the instrument.

   For Example: Thermocouple Amplifier Model 13-4715-40 Serial Number _____ .

2. Description of the part as listed in the manual.

3. Gould part number.

NOTE: Do not use the SYMBOL NUMBER from the parts list for identifying desired parts on the order.

GOULD THERMOCOUPLE AMPLIFIER
MODEL 13-4715-4X
FIGURE 6-1

ITEM NO	PART NUMBER	DESCRIPTION	SYMBOL NO
1	288303-103	Resistor, Variable	R102
2	230050-102	Resistor, Variable	R101
3	286151-3	Switch, Rotary	S102
4	248809	Connector	XCR101
5	9-281501-14	Connector	P201
	281506-1	Contact, Electrical	
6	888191-4X	Board Assembly (See Fig. 6-2)	
7	688106	Bracket Assembly	
8	See Fig. 6-2	Connector, Panel	J101
9	9-281501-8	Connector	J202
	281502-1	Contact, Electrical	
10	269960	Switch, Toggle	S101
11	788095	Bracket Assembly	
12	248808	Clip, Mounting	
13	286420-1	Diode, Led	CR101
14	784518	Panel Assy, Silkscreen	
15	285651-3	Knob	
16	663800-1	Nut, Knurled	
17	284990	Knob, Turns-Counting	
18	285650	Knob	
19	285652-1	Knob	
20	285651-2	Knob	
21	285653-1	Knob	
22	See Section 1.4	Connector, Thermocouple, Male (Not shown. Mates with J101)	P101

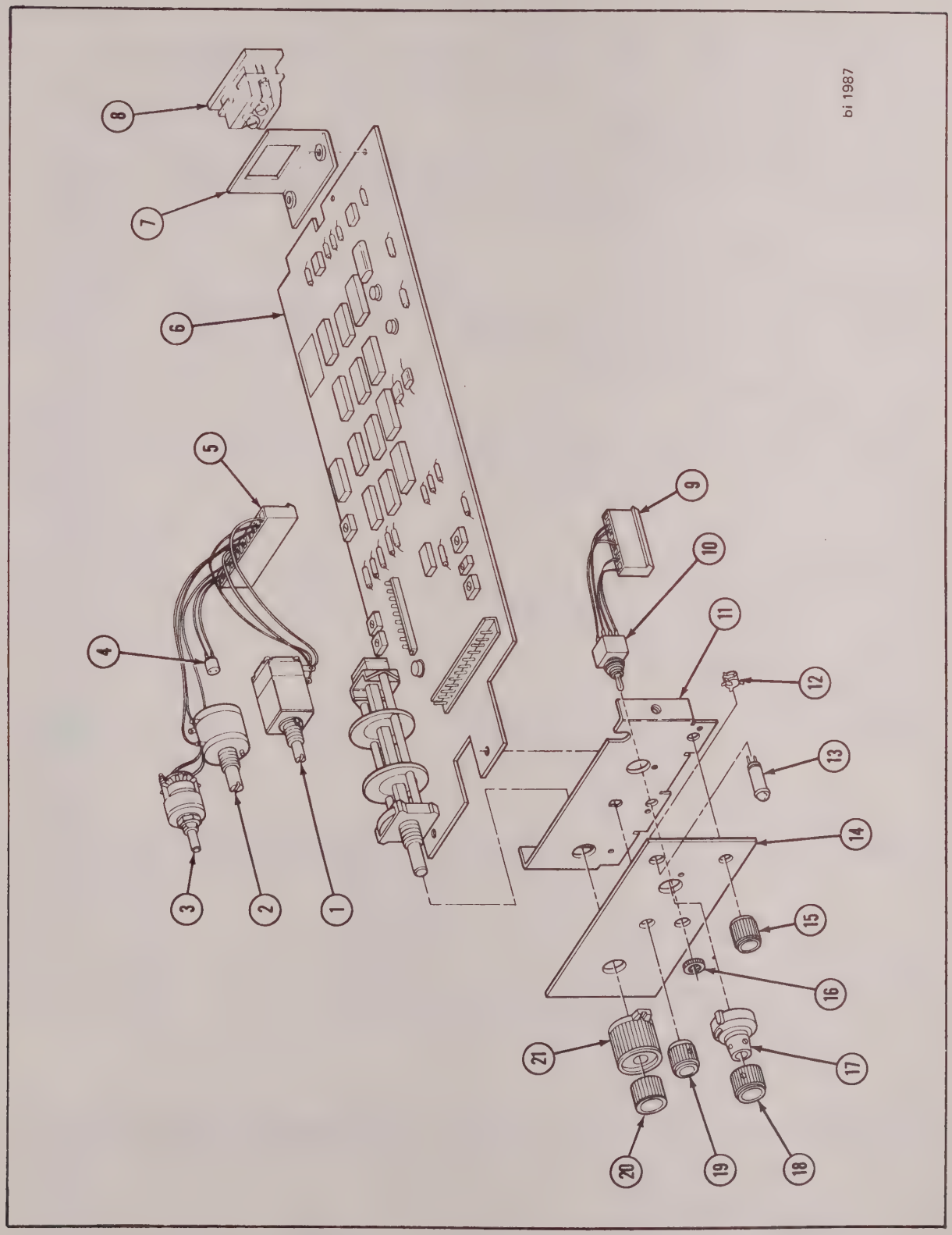


FIGURE 6-1 THERMOCOUPLE AMPLIFIER

GOULD THERMOCOUPLE AMPLIFIER, MODEL 13-4715-4X
ELECTRICAL PARTS LIST
BOARD ASSEMBLY (888191) With Thermocouple Panel Connector
FIGURE 6-2

MODEL NUMBER SUFFIX (13-4715– THERMOCOUPLE TYPE →		40 J	41 K	42 T	43 E	44 R	45 S
PART NUMBER	DESCRIPTION	SYMBOL NUMBER					
888193	BOARD, Subassy (See Fig.6-3)	–	–	–	–	–	–
269095-4	Compensator, no. JR384 D20	A201					
269095-1	A20		A201				
269095-2	B20			A201			
269095-3	C20				A201		
269095-7	F20					A201	
269095-5	Compensator, no. JR384 E20						A201
1-287918	RESISTOR NETWORK	U216					
1-28874 3			U216				
1-288745				U216			
1-288747					U216		
1-288922						U216	
1-288922							U216
2-287918		U217					
2-288743			U217				
2-288745				U217			
2-288747					U217		
2-288922						U217	
1-288939							U217
3-287918		U218					
3-288743			U218				
3-288745				U218			
3-288747					U218		
3-288922						U218	
2-288939							U218
4-287918		U219					
4-288743			U219				
4-288745				U219			
4-288747					U219		
4-288922						U219	
3-288939	RESISTOR NETWORK						U219
25-265969-10000	RESISTOR, 1000 ohm	R210					
25-265969-780R0	780 ohm		R210				
25-265969-758R0	758 ohm			R210			
25-265969-11700	1170 ohm				R210		
25-265969-143R5	143.5 ohm					R210	
25-265969-140R7	140.7 ohm						R210
25-265969-30000	3000 ohm	R248	R248	R248	R248		
25-265969-68001	RESISTOR, 68,000 ohm					R248	R248
288065-3	PANEL CONNECTOR	J101					
288065-1			J101				
288065-2				J101			
288065-4					J101		
288065-5						J101	
288065-5	PANEL CONNECTOR						J101

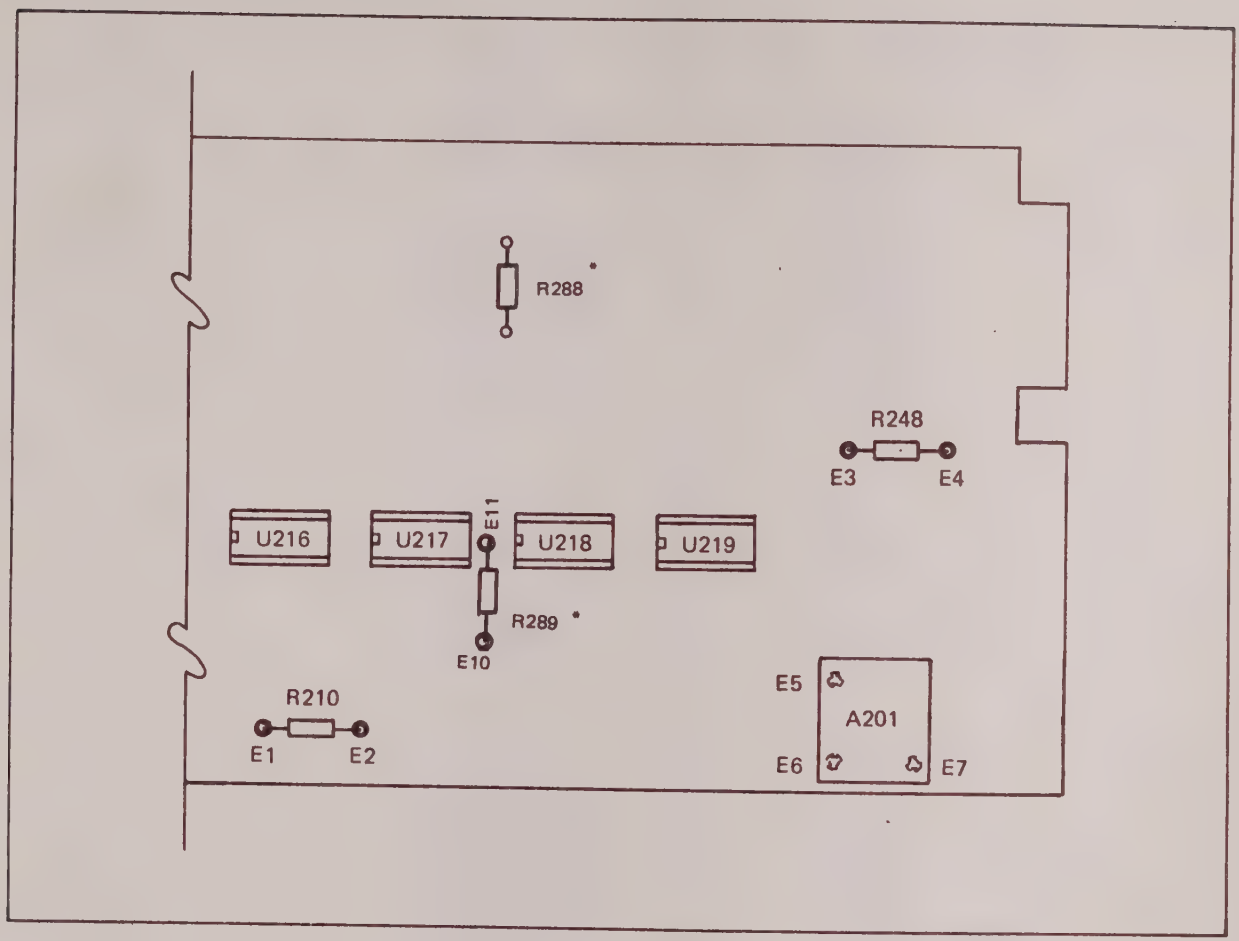


FIGURE 6-2 BOARD ASSEMBLY 888191-4X

*NOTE:

R289 on 13-4715-44 is 17.8K, P/N 25-265969-17801.
R289 on 13-4715-45 is 18K, P/N 25-265969-18001.
R288 on 13-4715-44 and 45 is 11.11K, P/N 25-265969-11111.
R288 and R289 not used on other Thermocouple types.

GOULD THERMOCOUPLE AMPLIFIER, MODEL 13-4715-4X
ELECTRICAL PARTS LIST
BOARD SUBASSEMBLY (888193)
FIGURE 6-3

SYMBOL NO	PART NUMBER	DESCRIPTION
C201	262585-106	Capacitor
C202	20-285066-1	Capacitor
C204	262585-106	Capacitor
C205	10-281282-255	Capacitor
C207, 208	262585-475	Capacitor
C209	10-241145-103	Capacitor
C210	240352-151	Capacitor
C211	240352-300	Capacitor
C212, 213	283943-330	Capacitor
CR205, 206	270508	Diode
CR207	280435-2	Diode
J201	281711-6	Connector
J201,202	281711-8	Connector
Q203, 204	286141	Transistor
R201	1-265969-10003	Resistor
R202	1-265969-10000	Resistor
R203	5-241111-153	Resistor
R204	5-241111-221	Resistor
R205	269085-203	Resistor, Variable
R206	5-241111-101	Resistor
R208	269085-102	Resistor, Variable
R209	25-265969-16001	Resistor
R210	See Fig. 6-2	Resistor
R211, 212	R1-281345-50000	Resistor
R213	1-265969-25000	Resistor
R214	269085-103	Resistor, Variable
R215	R1-281345-16780	Resistor
R216	5-241111-102	Resistor
R218	5-241111-101	Resistor
R220	5-241111-102	Resistor
R221	25-265969-10R00	Resistor
R222	5-241111-103	Resistor
R223	5-241111-824	Resistor
R224	5-241111-103	Resistor
R225	5-241111-472	Resistor
R226	5-241111-821	Resistor
R227	1-265969-800R0	Resistor
R228	R1-281345-20000	Resistor
R229	1-281284-103	Resistor, Variable

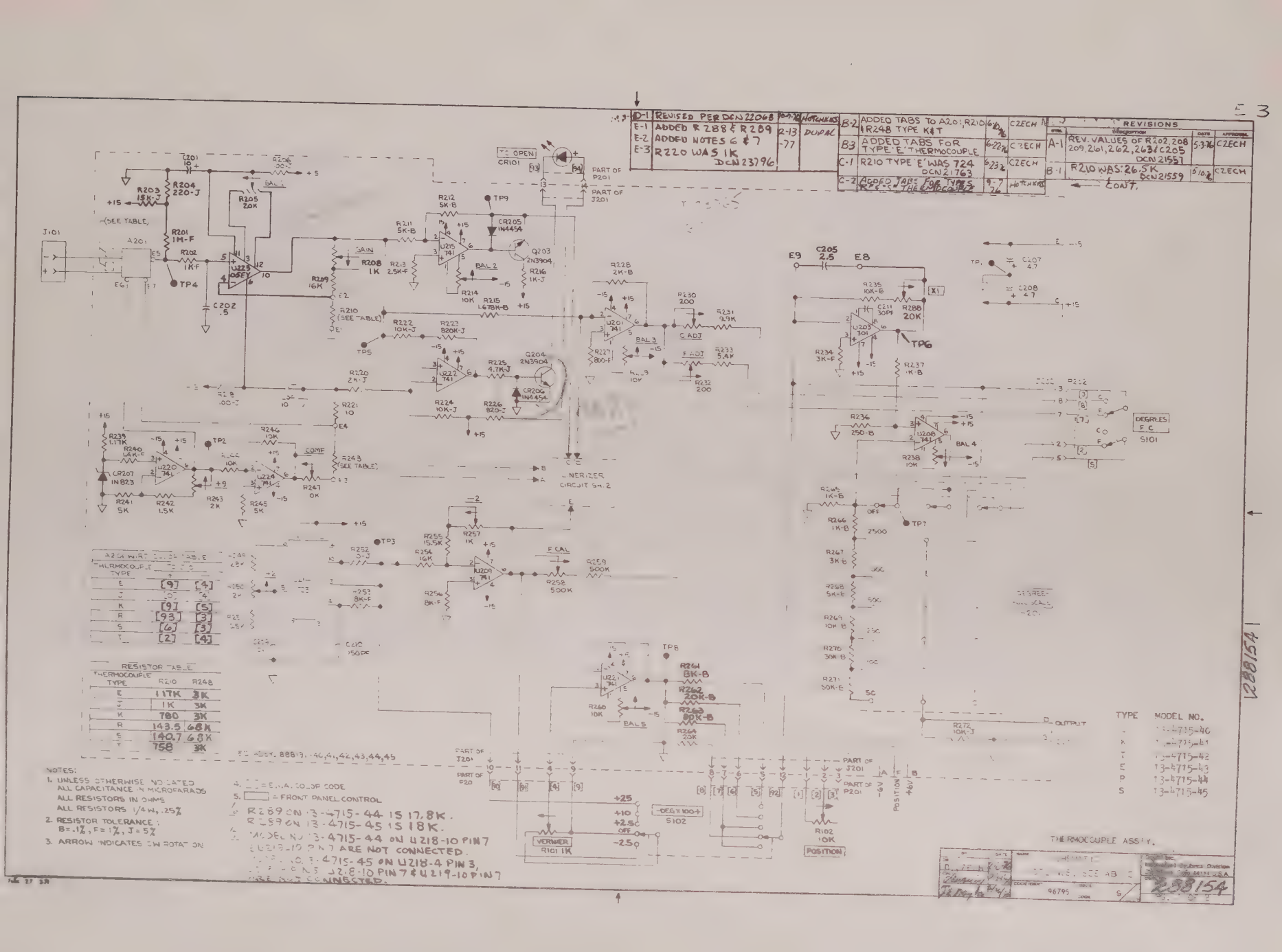
GOULD THERMOCOUPLE AMPLIFIER, MODEL 13-4715-4X
ELECTRICAL PARTS LIST (Cont'd)
BOARD SUBASSEMBLY (888193)
FIGURE 6-3

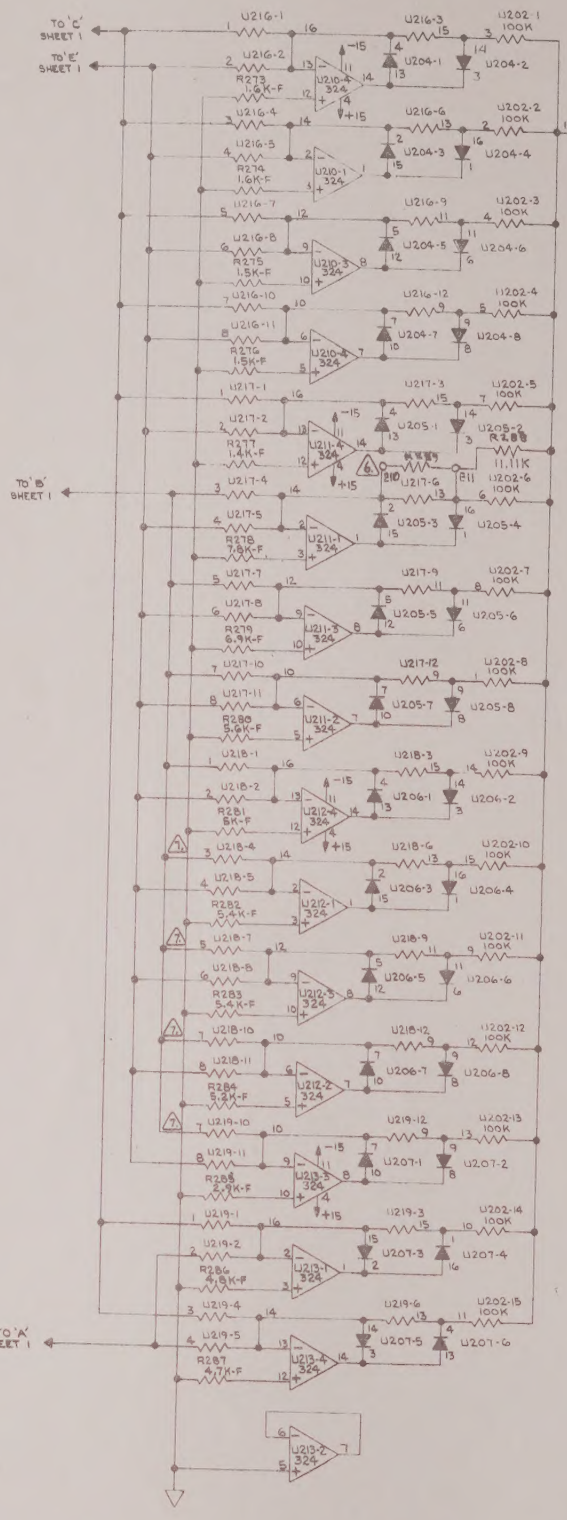
SYMBOL NO	PART NUMBER	DESCRIPTION
R230	284878-201	Resistor, Variable
R231	25-265969-99000	Resistor
R232	284878-201	Resistor, Variable
R233	25-265969-54000	Resistor
R234	1-265969-30000	Resistor
R235	R1-281345-10001	Resistor
R236	R1-281345-250R0	Resistor
R237	R1-281345-10000	Resistor
R238	269085-103	Resistor, Variable
R239	25-265969-11700	Resistor
R240	1-265969-14000	Resistor
R241	25-265969-50000	Resistor
R242	25-265969-15000	Resistor
R243	269085-202	Resistor, Variable
R244	25-265969-10001	Resistor
R245	25-265969-50000	Resistor
R246	25-265969-10001	Resistor
R247	269085-103	Resistor, Variable
R248	See Fig. 6-2	Resistor
R249	25-265969-28001	Resistor
R250	269085-202	Resistor, Variable
R251	25-265969-10501	Resistor
R252	5-241111-100	Resistor
R253	1-265969-80000	Resistor
R254	25-265969-16001	Resistor
R255	25-265969-15501	Resistor
R256	1-265969-80000	Resistor
R257	284878-102	Resistor, Variable
R258	269085-504	Resistor, Variable
R259	25-265969-50002	Resistor
R260	284878-103	Resistor
R261	R1-281345-80000	Resistor
R262	R1-281345-20001	Resistor
R263	R1-281345-80001	Resistor
R264	25-265969-20001	Resistor
R265, 266	R1-281345-10000	Resistor
R267	R1-281345-30000	Resistor
R268	R1-281345-50000	Resistor
R269	R1-281345-10001	Resistor
R270	R1-281345-30001	Resistor
R271	R1-281345-50001	Resistor
R272	5-241111-103	Resistor
R273, 274	1-265969-16000	Resistor
R275, 276	1-265969-15000	Resistor
R277	1-265969-14000	Resistor
R278	1-265969-78000	Resistor
R279	1-265969-69000	Resistor
R280	1-265969-56000	Resistor
R281	1-265969-50000	Resistor
R282, 283	1-265969-54000	Resistor
R284	1-265969-52000	Resistor

GOULD THERMOCOUPLE AMPLIFIER, MODEL **13-4715-4X**
ELECTRICAL PARTS LIST (Cont'd)
BOARD SUBASSEMBLY (**888193**)
FIGURE 6-3

SYMBOL NO	PART NUMBER	DESCRIPTION
R285	1-265969-29000	Resistor
R286	1-265969-48000	Resistor
R287	1-265969-47000	Resistor
R288, S201	288103	SWITCH, Rotary, with variable resistor
U201	280863-3	Integrated Circuit
U202	1-283274-104	Resistor Network
U203	230062-1	Integrated Circuit
U204,205,206,207	288069	Diode Array
U208	281287	Integrated Circuit
U209	280863-3	Integrated Circuit
U210,211,212,213	287740	Integrated Circuit
U214	280439-2	Integrated Circuit
U215	280863-3	Integrated Circuit
U216,217,218,219	See Fig. 6-2	RESISTOR NETWORK
U220,221,222	280863-3	Integrated Circuit
U223	288071-1	Integrated Circuit
U224	280863-3	Integrated Circuit

FIGURE 6-3 BOARD SUBASSEMBLY (888193)


REVISIONS
D-1 REVISED PER DCN 22068
E-1 ADDED R288 & R289
E-2 ADDED NOTES 6 & 7
E-3 R220 WAS 1K DCN 23796
B-2 ADDED TABS TO A20, R210 & R248 TYPE K&T
B3 ADDED TABS FOR TYPE 'E' THERMOCOUPLE
C-1 R210 TYPE 'E' WAS 724 DCN 2763
C-2 ADDED TABS FOR TYPES R, S & T THERMOCOUPLE
A-1 REV. VALUES OF R202, 208, 209, 261, 262, 263 & C205 DCN 21557
B-1 R210 WAS 26.5K DCN 21559
CONT.
A20
J101
J201
P201
P20
R201 1M-F
R202 1K-F
R203 15K-J
R204 220-J
R205 20K
R206 100
R208 1K
R209 16K
R210 (SEE TABLE)
R211 5K-B
R212 5K-B
R213 2.5K-F
R214 10K
R215 1.67K-B
R216 1K-J
R220 2K-J
R221 10
R222 10K-J
R223 820K-J
R224 10K-J
R225 4.7K-J
R226 820-J
R227 800-F
R228 2K-B
R230 200
R231 9.9K
R232 200
R233 5.4K
R234 3K-F
R235 10K-B
R236 250-B
R237 1K-B
R238 10K
R239 1.17K
R240 6.4K-C
R241 5K
R242 1.5K
R243 (SEE TABLE)
R244 10K
R245 5K
R246 10K
R247 0K
R252 3-J
R253 8K-F
R254 16K
R255 15.5K
R256 8K-F
R257 1K
R258 500K
R259 500K
R260 10K
R261 8K-B
R262 20K-B
R263 80K-B
R264 20K
R265 1K-B
R266 1K-B
R267 3K-B
R268 5K-B
R269 10K-B
R270 30K-B
R271 50K-B
R272 10K-J
C201 10
C202 .5
C205 2.5
C207 4.7
C208 4.7
C209 .001
C210 150PF
C211 30PF
U201 741
U202 301
U203 741
U204 741
U205 741
U206 741
U207 741
U208 741
U209 741
U210 741
U211 741
U212 741
U213 741
U214 741
U215 741
U216 741
U217 741
U218 741
U219 741
U220 741
U221 741
U222 741
U223 OSEY
U224 741
CR101 LED
CR205 1N4454
CR206 1N4454
CR207 1N823
Q203 2N3904
Q204 2N3904
TP1
TP2
TP3
TP4
TP5
TP6
TP7
TP8
TP9
X1
+15
-15
+5
+9
-9
BAL 1
BAL 2
BAL 3
BAL 4
BAL 5
GAIN
COMP
C ADJ
F ADJ
F CAL
VERNIER R101 1K
R102 10K POSITION
S101 DEGREES F C
S102 -DEG X 100+
DEGREES FULL SCALE -200
OUTPUT
POSITION -6V +6V
PART OF J201
PART OF P201
PART OF J20
PART OF P20
THERMOCOUPLE ASSY.
TYPE MODEL NO.
K 13-4715-41
T 13-4715-42
E 13-4715-43
P 13-4715-44
S 13-4715-45
A20 UNIT CALIB TABLE
THERMOCOUPLE TYPE
E [9] [4]
J [9] [4]
K [9] [3]
R [93] [3]
S [6] [3]
T [2] [4]
RESISTOR TABLE
THERMOCOUPLE TYPE R210 R248
E 1.17K 3K
J 1K 3K
K 780 3K
R 143.5 68K
S 140.7 68K
T 758 3K
ED. INDEX. 88819: 40,41,42,43,44,45
NOTES:
1. UNLESS OTHERWISE INDICATED ALL CAPACITANCE IN MICROFARADS ALL RESISTORS IN OHMS ALL RESISTORS 1/4W, .25%
2. RESISTOR TOLERANCE: B=.1%, F=1%, J=5%
3. ARROW INDICATES CW ROTATION
4. = E.M.A. COLOR CODE
5. = FRONT PANEL CONTROL
R289 ON 13-4715-44 IS 17.8K.
R289 ON 13-4715-45 IS 18K.
MODEL NO 13-4715-44 ON U218-10 PIN 7 U218-10 PIN 7 ARE NOT CONNECTED.
MODEL NO. 13-4715-45 ON U218-4 PIN 3, CONNECTIONS U218-10 PIN 7 & U219-10 PIN 7 ARE NOT CONNECTED.
THERMOCOUPLE ASSY.
DEGREES F
Hewlett-Packard Loveland Division
Loveland, Colorado U.S.A.
1288154
96795
1288154
E3



SUFFIX	RESISTOR NETWORK DESIGNATION U216- THEREMOCOUPLE TYPE					
	E	J	K	T	R	S
1	1.0K	1.0K	1.0K	1.0K	1.0K	1.0K
2:1	15.69	15.95	17.24	17.93	2.0	2.0
3:1	25.716	18.0	19.51	20.46	2.0	2.0
4	1.0K	1.0K	1.0K	1.0K	1.0K	1.0K
5:4	17.665	17.83	19.31	20.72	2.0	2.0
6:4	19.09	13.55	14.32	14.29	2.0	2.0
7	1.0K	1.0K	1.0K	1.0K	1.0K	1.0K
8:7	31.875	21.3	22.91	25.31	2.0	2.0
9:7	13.47	9.23	11.93	9.82	2.0	2.0
10	1.0K	1.0K	1.0K	1.0K	1.0K	1.0K
11:10	29.87	27.4	31.36	33.83	2.0	2.0
12:10	9.669	6.81	8.49	8.86	2.0	2.0

SUFFIX	RESISTOR NETWORK DESIGNATION U217- THERMOCOUPLE TYPE					
	E	J	K	T	R	S
1	1.0K	1.0K	1.0K	1.0K	1.0K	1.0K
2:1	53.507	47.68	59.98	68.57	2.0	2.0
3:1	6.927	5.37	6.18	7.13	2.0	2.0
4	10.0K	10.0K	10.0K	10.0K	10.0K	10.0K
5:4	2.0	2.0	2.0	2.0	11.92	9.184
6:4	4.064	3.549	2.98	4.04	15.89	16.07
7	10.0K	10.0K	10.0K	10.0K	10.0K	10.0K
8:7	44.12	44.83	37.54	55.28	3.91	3.28
9:7	4.577	2.301	1.37	4.78	4.74	3.057
10	10.0K	10.0K	10.0K	10.0K	10.0K	10.0K
11:10	19.287	18.224	8.35	24.86	2.41	2.237
12:10	3.697	1.382	2.41	3.87	3.075	2.651

SUFFIX	RESISTOR NETWORK DESIGNATION U218- THERMOCOUPLE TYPE					
	E	J	K	T	R	S
1	10.0K	10.0K	10.0K	10.0K	10.0K	10.0K
2:1	10.595	4.231	1.0	14.95	2.014	1.67
3:1	2.759	1.3541	1.0	3.07	2.23	2.167
4	10.0K	10.0K	10.0K	10.0K	10.0K	10.0K
5:4	6.629	3.629	1.0	10.17	1.61	2.0
6:4	1.859	1.7655	1.0	2.80	1.7	2.0
7	10.0K	10.0K	10.0K	10.0K	10.0K	10.0K
8:7	1.0	3.268	1.0	7.41	1.259	2.0
9:7	1.0	1.813	1.0	2.25	1.09	2.0
10	10.0K	10.0K	10.0K	10.0K	10.0K	10.0K
11:10	1.0	2.960	1.0	3.56	2.0	2.0
12:10	1.0	1.7644	1.0	1.72	2.0	2.0

SUFFIX	RESISTOR NETWORK DESIGNATION U219- THERMOCOUPLE TYPE					
	E	J	K	T	R	S
1	10.0K	10.0K	10.0K	10.0K	10.0K	10.0K
2:1	2.704	2.291	15.97	1.0	1.002	1.025
3:1	.8962	1.560	1.06	1.0	.676	.87
4	10.0K	10.0K	10.0K	10.0K	10.0K	10.0K
5:4	2.2	2.132	2.75	1.0	.895	.956
6:4	1.942	1.544	3.44	1.0	1.185	2.27
7	10.0K	10.0K	10.0K	10.0K	10.0K	10.0K
8:7	1.0	1.0	1.0	1.0	2.0	2.0
9:7	1.0	1.0	1.0	1.0	2.0	2.0
10	10.0K	10.0K	10.0K	10.0K	10.0K	10.0K
11:10	4.287	2.630	5.06	4.68	2.0	2.0
12:10	1.019	.4838	.695	.917	2.0	2.0

THERMOCOUPLE ASSY.

SCHEMATIC
MODEL NOS. SEE PG. 1

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REVISIONS

2881541

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